NITROGEN TETROXIDE FLOW DECAY STUDY

FOR THE ORBITAL WORKSHOP PROPULSION SYSTEM

CONTRACT NAS 8-21489

FINAL REPORT 12243-6002-R000

JUNE 1969

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

ALABAMA 35812

TRW SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH • CALIFORNIA

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under Contract NAS 8-21489

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FOREWORD

This report was prepared by TRW Systems Group, Redondo Beach, California, and describes the results of a nitrogen tetroxide flow decay study performed on the Orbital Workshop Propulsion System. The work described was accomplished between December 26, 1968 and May 26, 1969 for the George C. Marshall Space Flight Center, Huntsville, Alabama. The NASA technical manager was Mr. Keith Coates.

The work performed on the program was accomplished by TRW Systems Group, Science and Technology Division. Mr. M. J. Makowski of the Applied Research Section of the Applied Technology Department was the program manager. The technical efforts provided by several TRW Systems Group personnel are acknowledged:

Mr. C. Armstrong	Applied Technology Department, Technology Laboratory
Dr. E. Burns	Chemistry & Chemical Engineering Department, Science and Technology Division
Mr. M. Gardner	Chemistry & Chemical Engineering Department, Science and Technology Division
Mr. A. Grunt	Chemistry & Chemical Engineering Department, Science and Technology Division
Mr. J. Morris	Inglewood Rocket Test Facility, Science and Technology Division
Mr. J. Reger	Materials Science Department, Physical Research Center
Mr. D. Wells	Chemistry & Chemical Engineering Department, Science and Technology Division

ABSTRACT

This report describes the results of a flow decay study performed on the N_2O_4 feed lines, valves, and filters of the Orbital Workshop Propulsion System. The system was exposed to off limit (high and low) environmental temperatures during the course of the flow experiments. Additional efforts were directed toward the effect of oxidizer compatibility with the braze alloy planned for system assembly, and upon the effects of artificial propellant aging.

Engine flow variations did not exceed 10 percent when operating between 90°F and 50°F using specification grade nitrogen tetroxide, and 12 percent when using artificially aged propellant. Isolation valve variations did not exceed 9 percent when operating between 90°F and 50°F using specification grade and 7 percent when using artificially aged nitrogen tetroxide.

Engine flow decay did not exceed 10 percent when operating between 90°F and 50°F using specification grade nitrogen tetroxide, and 5 percent when using artificially aged propellant. Isolation valve flow decay did not exceed 4 percent when operating between 90°F and 50°F using specification grade nitrogen tetroxide, and 5 percent when using artificially aged propellant.

Of the twenty-seven runs performed with the feed tank and test system between 90°F and 50°F, eight runs exhibited engine flow decays greater than 2 percent, and ten runs exhibited isolation valve flow decays greater than 2 percent.

These results cannot be indiscriminately applied to other systems or other operating conditions as significant differences in flow decay characteristics due to geometry or service environment could occur.

Several potential flow decay problem solution concepts are presented, however, no completely reliable method of flow decay control is presently available.

Recommendations are made for further flow decay related testing of the OWPS.

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (CON'T.)

ILLUSTRATIONS (CON'T)

TABLES

1.0 INTRODUCTION

This report presents the results of a Flow Decay Study for the Orbital Workshop Propulsion System sponsored by the NASA George C. Marshall Space Flight Center. The presentation includes a description of the test apparatus and test procedure, as well as test data and results of chemical analysis and compatibility studies performed. Conclusions, recommended problem solutions and recommendations for further work are presented.

1.1 BACKGROUND

Flow decay and flow stoppage have occurred in nitrogen tetroxide (NTO) flow systems containing fine filters and small clearances. This flow degradation has been investigated by TRW Systems under NASA Contracts NAS 7-107 and NAS 7-549. The clogging mechanism has been postulated to be the solvation, coagulation and final precipitation of complex iron colloids from the solution with eventual drying of the gel resulting in a crystalline powder-like residue. The phenomenon appears as an increase in NTO viscosity in high velocity flow and seems to occur in areas of turbulence and constriction such as entrances to valves, filters, orifices and capillaries. Flow blockage was observed in both capillary and filter flow tests using MSC-PPD-2A NTO as well as propellant doped with metal ions likely to be found in an aged system. The blockage was caused by a gel-like material found at the entrance to the capillary and filter which dried to a powdery crystalline residue. Changes in propellant temperature appear to be an important factor in inducing the flow decay process. The clogging material has been analyzed and found to contain iron complexes resulting from reactions between NTO, soluble impurities, and ferrous alloys used in constructing the system. Organic material has also been detected, which may synergistically contribute to the flow decay phenomenon. These analyses were performed utilizing infrared spectrometric, X-ray fluorescence and atomic absorption techniques.

The NTO flow decay phenomenon has been observed by other investigators at Rocketdyne, NASA, Aerospace, and McDonnell Douglas. Publications relating to this problem are found in References 1 through 6.

Flow decay in NTO systems may be caused by gel formation, formation of solids, static accumulation of corrosion products and gas saturation of the propellant.

TRW Systems Group has demonstrated flow decay due to gel formation under Contract NAS 7-549 (References 2 and 9). The gel is postulated to form from a colloidal solution brought about by physico-mechanical means (References 7, 8, 9). Particles in colloidal dispersions (0.001 micron to 0.1 micron) are larger than most molecules in solution but not large enough to settle out because of gravity, or be seen with a conventional microscope. These colloidal particles can become solvated, and form gelatinous precipitates. In the process of going from a colloidal particle to a solvated precipitable particle, the diameter may increase on the order of a thousand times or more, and may be capable of being filtered or clogging small clearances. It is readily apparent that such a process can have profound effects on the rheological properties of the propellant.

Solids have been found to form in NTO flow systems during studies performed by Rocketdyne (Reference 4). In these flow tests solids were observed to be deposited on a valve pintle during a flow run.

Corrosion products are formed due to NTO interaction with the storage tank and flow system materials. When system temperatures are reduced these dissolved contaminants precipitate out of solution. An increase in system temperature causes further interaction with system materials resaturating the solution. Thus, temperature cycling causes an accumulation of solid corrosion products in the system which could clog filters, orifices and capillaries. In addition to the effects of temperature cycling, high static temperatures have been shown to cause substantial growth of a gelatinous material when N_2O_4 is exposed to stainless steels and other nickel bearing alloys (Reference 10).

Nitrogen saturation of NTO may cause flow decay (Reference 10), however, this mechanism is beyond the scope of this program and was not considered further; therefore, precautions were taken to minimize NTO gas saturation during the flow runs.

TRW Systems has identified and isolated the NTO flow decay phenomena on two NASA programs, NAS 7-107 and NAS 7-549, and is currently engaged in further work in this area. It is felt that flow tests of actual systems, valves, and components, as performed during this study, are a logical extension of previous and existing programs.

1.2 PROGRAM APPROACH

Prior to this program, flow decay investigations were performed on components and test sections simulating components, rather than on complete systems. This test program was undertaken to systematically test an entire propellant feed system over a range of temperatures in order to identify those conditions which could cause flow degradation. Thus, while the actual interaction of system components, in a flow decay sense, might not be fully understood the possibility of flow decay in the full operating system might be assessed. In order to identify which part of the system was the major contributor to overall system flow degradation, all system components were instrumented to provide temperature, differential pressure and flow information. Temperature conditioning and data taking were automated as much as possible to minimize the chance of error.

The data was processed to eliminate as many variables as possible from consideration before being examined for flow decay trends. As much of the basic and processed data as possible has been presented in this report to allow independent assessment of the results obtained. Both equivalent area and percent corrected flow presentations are utilized for the convenience of the user.

Chemical analyses were applied to the propellant at every stage of testing and these results are likewise presented as fully as possible to allow independent evaluation.

2.0 ORBITAL WORKSHOP PROPULSION SYSTEM EXPERIMENTAL APPARATUS

The test apparatus used on the program consisted of the government furnished Orbital Workshop Propulsion System (OWPS) components assembled on a holding fixture, the test instrumentation, the propellant feed and catch systems, and the system environmental temperature control box.

The OWPS, as supplied, consisted of two Marquardt Model R-IE-002, 22 pound thrust rocket engines, a dual redundant isolation valve assembly per Marquardt drawing 231350, two 15 micron absolute Wintec filters, NASA Part No. SK 20-4612, and connecting manifolds as described in NASA MSFC drawing No. SK 20-4458. The engines are more fully described in Marquardt Report MIR No. 272, which is summarized in Appendix I.

The above components were assembled to a supporting frame as described in NASA drawing No. SK 20-4458. The system, as installed in the environmental box for test, is shown in Figure 2-1. The test instrumentation was assembled into the OWPS and consisted of a differential pressure transducer across each system valve and filter, thermocouples at each system component inlet and outlet, and a system pressure transducer mounted to the engine feed manifold. In addition to the instrumentation mounted on the OWPS itself, pressure transducers were mounted to the feed and catch tanks, thermocouples were attached to the surface of the feed tank, and a thermocouple probe was inserted into the bulk propellant. Instrumentation location and type is detailed in the schematic diagram of the test setup, Figure 2-2. The instrumentation used is listed in Appendix II. Instrumentation accuracies and data reduction uncertainties are presented in Sections 3.3.1 and 4.1.1, respectively.

The propellant feed system consisted of a 60 gallon stainless steel tank with provision for regulated pressurization and for heating and cooling the NTO for temperature conditioning. Heating was accomplished through the use of electrical strip heaters bonded to the tank's surface and cooling was provided by injecting cold nitrogen gas from a liquid nitrogen vessel between

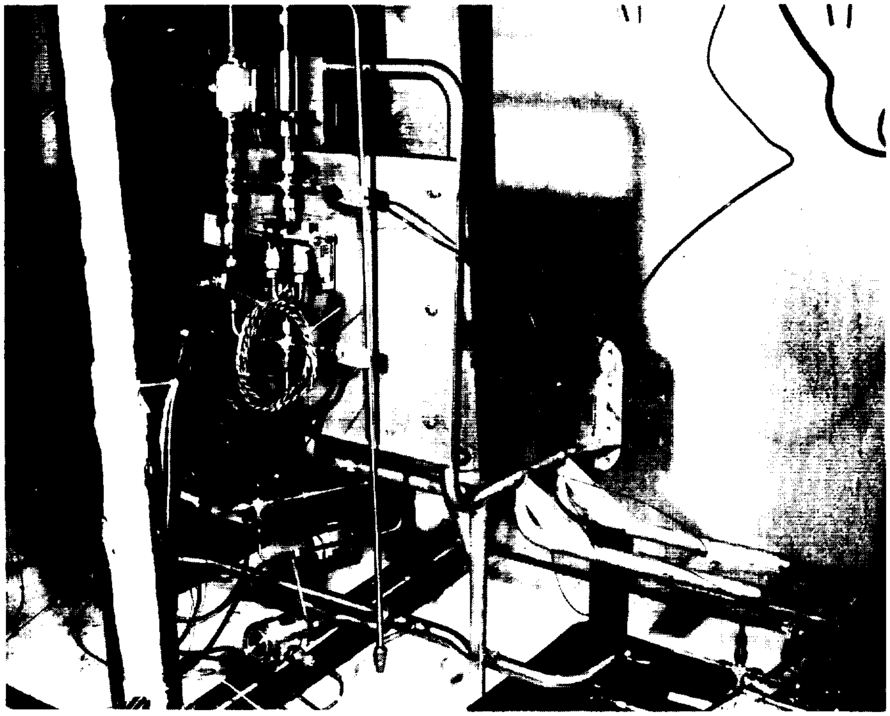

Figure 2-la. Installed Test Hardware

Figure 2-la. Installed Test Hardware

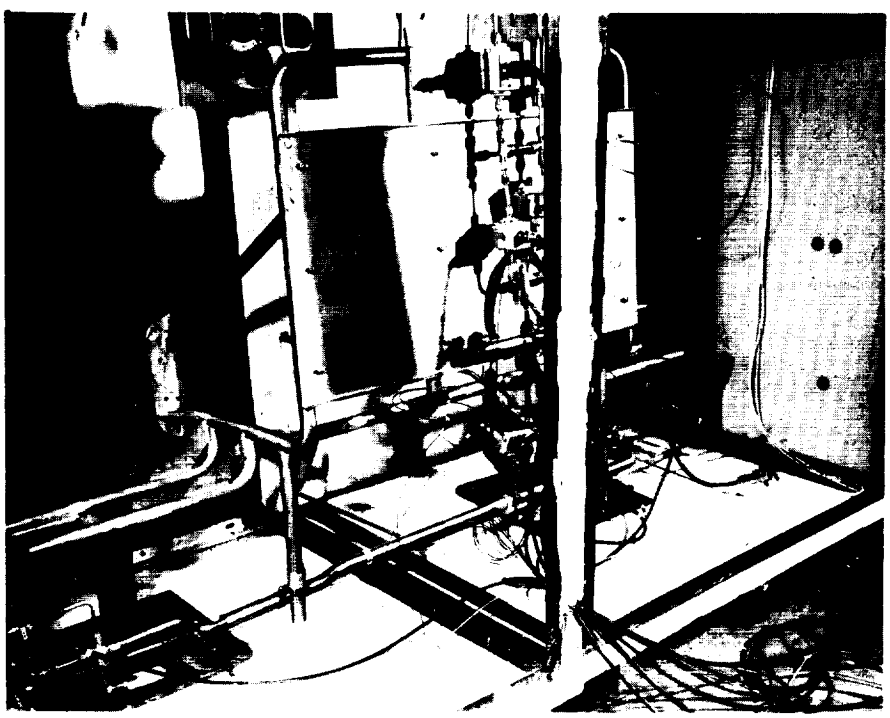

Figure 2-lb. Installed Test Hardware

Figure 2-lb. Installed Test Hardware

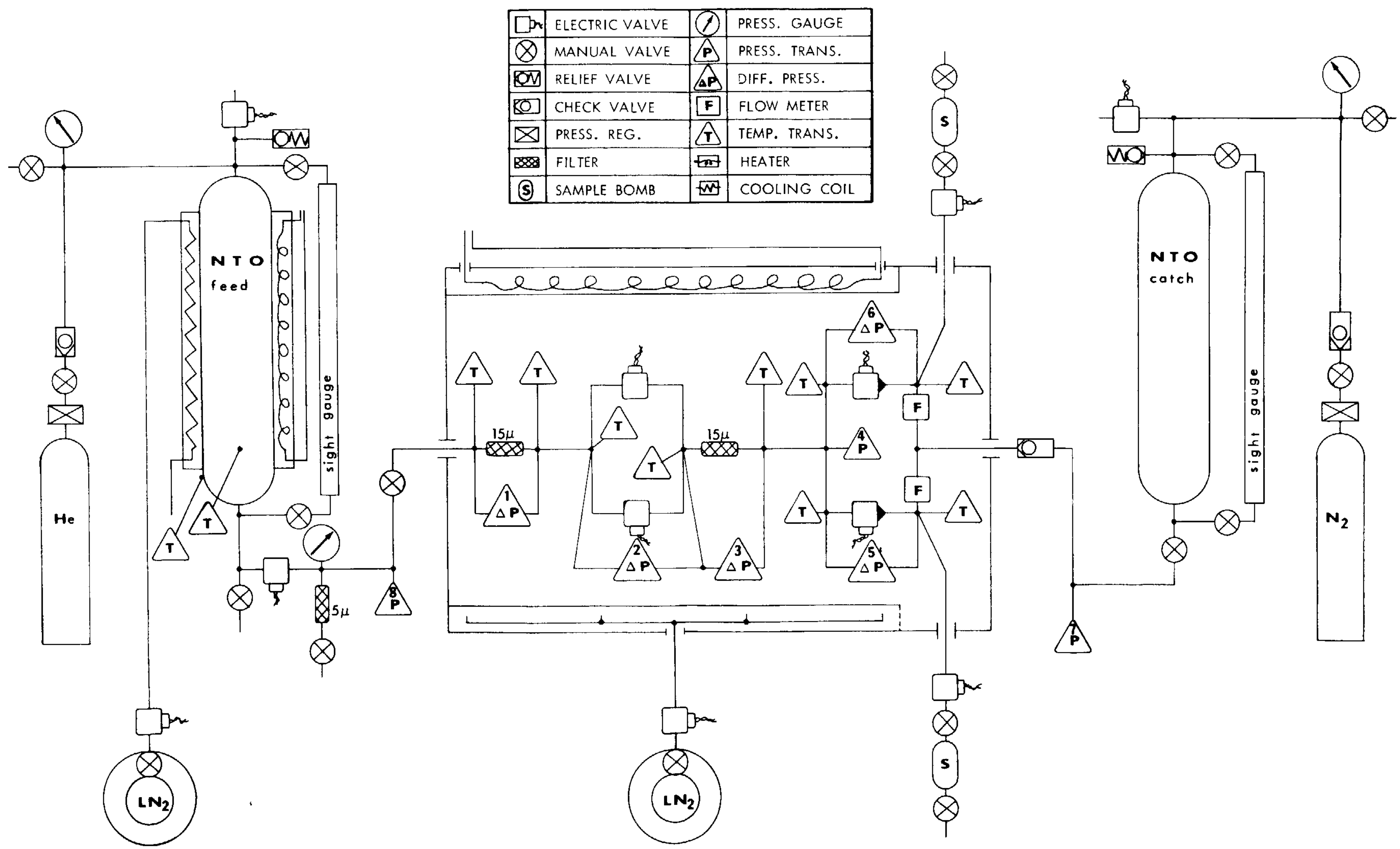

Figure 2-2. Schematic - NTO Flow Decay System

a cooling shroud and the tank. Figure 2-3 shows the general test cell arrangement and the feed tank with the cooling shroud in place before the shroud was insulated with spun fiberglass insulation. A high temperature "thermal blanket" type insulation was used over the heaters separating them from the cooling shroud. The nitrogen cooling gas was flowed through the passages formed between the heaters and insulation, and was enclosed by the cooling shroud. A cross-section of the arrangement is shown in Figure 2-4.

The propellant catch system consisted of a stainless steel tank identical to the feed tank but without heating and cooling provisions. Pressurization and vent provisions were made to allow maintaining the catch tank at a predetermined pressure to simulate engine chamber pressure.

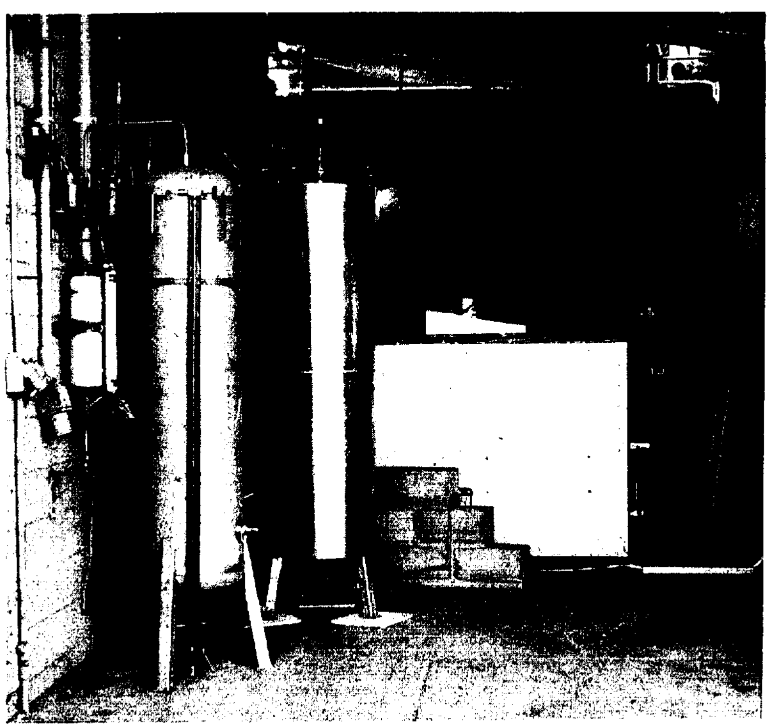

Figure 2-3. Test Cell

The environmental temperature control box was an insulated chamber provided with electrical heating and cold nitrogen cooling.

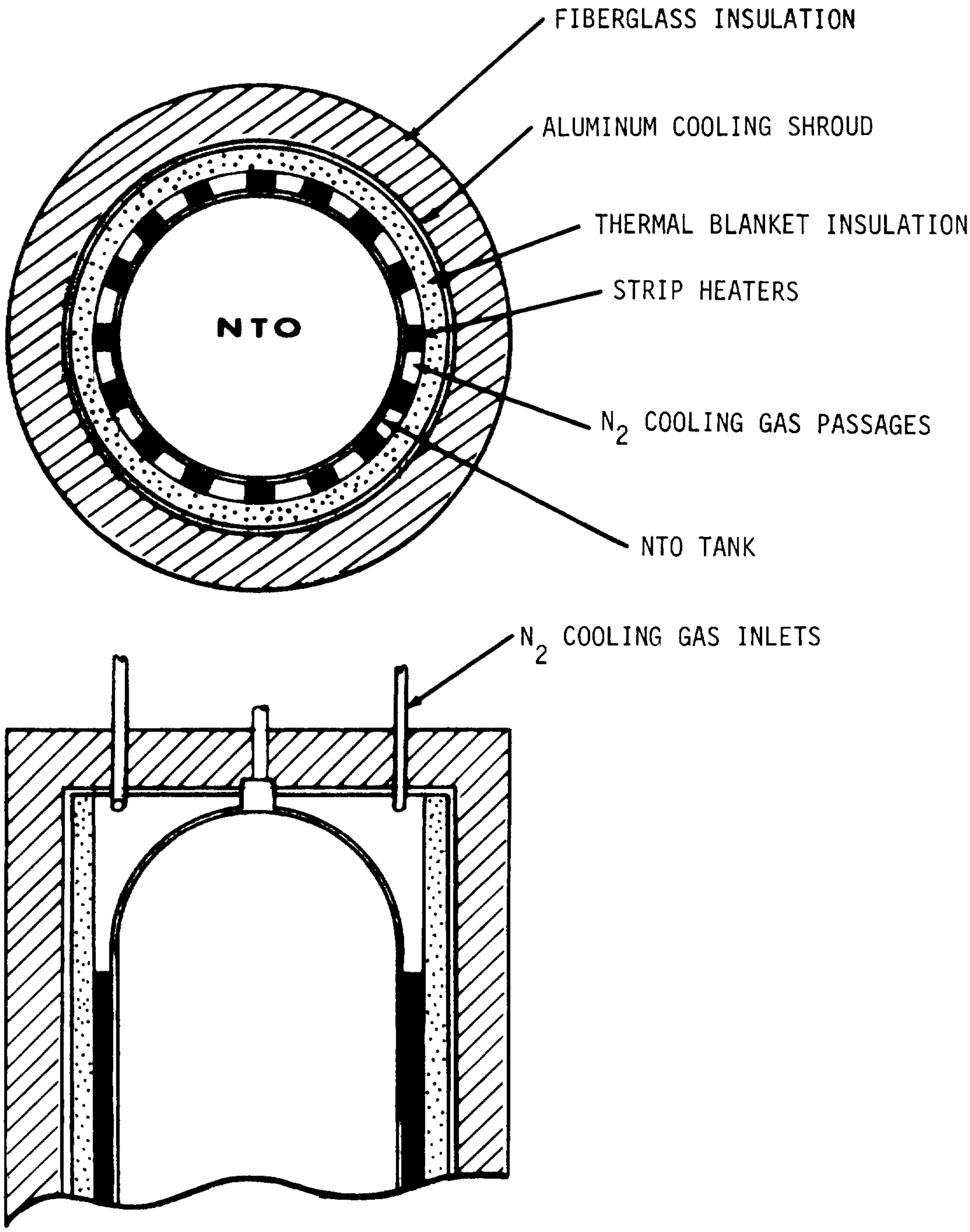

Figure 2-4. Propellant Feed Tank Heat and Cooling Configuration

3.0 ORBITAL WORKSHOP PROPULSION SYSTEM EXPERIMENTAL PROCEDURE

The experimental procedure was designed to maximize the amount of data collected while minimizing the number of runs required. The basic procedure followed is described in the Test Plan and Procedure presented as Appendix II.

3.1 FLOW TEST PROCEDURE

The testing proceeded as follows: The system feed tank was filled with NTO per MSC-PPD-2 and a sample was drawn for chemical analysis. The feed tank was temperature conditioned to the propellant temperature planned for the next test run and the system conditioned to its test temperature. After the required temperature conditions were well stabilized, the feed tank and catch tank pressures were established and the pressure transducer calibrations checked. Helium was used as the pressurant and the feed tank was vented to NTO vapor pressure following each run sequence to prevent NTO gas saturation. The isolation valves were then opened and a few seconds later the engine valves were opened on a steady state or pulsed basis for the required run duration. During the run, differential pressure recordings were made across each valve and filter, the flow rates from each engine were recorded, propellant temperatures at the inlet and outlet of each component were recorded, and feed tank, system, and catch tank pressures were monitored and recorded.

There was no attempt made to maintain a feed tank to system temperature difference during a flow run. Once the appropriate initial temperature differences had been established, the system was allowed to follow the incoming propellant temperature controlled only by its own thermal inertia. This was felt to more closely simulate the anticipated system thermal environment than would a constant temperature gradient.

Temperature conditioning of the propellant was accomplished by applying electrical power to the heaters or cold nitrogen gas from a liquid nitrogen cylinder to the feed tank as described in Section 2.0. Temperature conditioning of the system was accomplished by applying electrical power to the environmental box heaters or injecting cold nitrogen gas, from a liquid nitrogen cylinder, into the box. The feed tank and box heating/cooling arrangements were controlled by a pair of automatic recording controller units to allow unattended operation.

Electrical valves were plumbed to the system just downstream of each engine to allow sample taking during a flow run. Samples were routinely taken during the first run at each temperature condition, or if any flow anomalies were observed during the run. The sample bottles were normally purged with filtered gaseous nitrogen to eliminate oxygen which could give a false low NO reading due to oxidation of some NO to NO_2.

After each run the data was reduced at several points along the continuously recorded data tapes and computer processed to correct for the effects of pressure and temperature.

3.2 FLOW TEST SEQUENCE

The test matrix performed during this study is presented in Table 3-1. The test conditions were revised from those originally planned and presented in Table 1 of Appendix II due to observed occurrences of flow decay during the initial test sequence. A revision in the test plan and sequence following the initial test series was necessary since flow decay was observed during the 150°F propellant to 12°F system test runs. All the temperatures listed are nominal, reading tolerances are listed in Section 3.3.1 and Appendix II, while actual test temperatures for each component are presented in Appendix V. Initially, both isolation valves were opened during a test run and separate runs were made with left engine, right engine and both engines. However, after the initial test series all test runs were made with both engines and after run 15, only one isolation valve was opened since it was indicated by NASA that this more closely reproduced the system's probable use mode. Both steady state and pulsed mode operation was employed during the flow tests. Flow tests at each temperature condition were performed on both a steady state followed by pulse run and pulse run followed by steady state basis. This was done to examine the possible interaction between steady state and pulsed operation. A three to four second steady state flow was employed at the beginning and every 60 seconds throughout most pulse runs to obtain stabilized flow and pressure data.

Table 3-1. Test Matrix

Run	Engines Used (1)	Iso Valve(s) Used	Run Duration (sec)	Nominal Hold Tank Temp.°F	Nominal System Temp.°F	Propellant
1	Right	Both	1070	150	150	Neat NTO
2	Right/Both	"	1280	150	150	per MSC-
3	Left/Both	"	1105	150	75	PPD-2
4	Left	"	600	150	75	
5	Left	"	600	150	12	
6	Right	"	600	150	12	
7	Both	"	600	150	12	
8	"	"	100	58	58	
9	"	"	620 (3)	70	60	
10	"	"	480 (2)	70	60	
11	(4)	-	-	-	-	-
12	"	"	400 (3)	70	50	
13	"	"	600 (2)	70	50	
14	"	"	600 (3)	90	50	
15	"	"	400 (2)	90	50	
16	"	Right	200 (2)	12	150	
17	"	Left	300	12	150	
18	"	Right	570 (2)	12	12	
19	"	Left	610 (3)	12	12	
20	"	Right	360 (2)	90	90	
21	"	Left	360 (3)	90	90	
22	"	Right	360 (2)	70	70	
23	"	Left	360 (3)	70	70	
24	"	Right	360 (2)	50	50	
25	"	Left	360 (3)	50	50	
26	"	Right	300 (3)	30	30	
27	"	Left	360 (2)	30	30	
28	"	Both	81	30	30	
29	"	Left	360 (2)	90	70	
30	"	Right	360 (3)	90	70	
31	"	Left	360 (2)	90	50	
32	"	Right	362 (3)	90	50	
33	"	Left	360 (3)	90	90	Artifici-
34	"	Right	360 (2)	90	90	ally Aged
35	"	Left	360 (3)	70	70	
36	"	Right	362 (2)	70	70	NTO
37	"	Left	360 (3)	50	50	"
38	"	Right	360 (2)	50	50	"
39	"	Left	360 (3)	90	70	"
40	"	Right	360 (2)	90	70	"
41	"	Left	360 (3)	90	50	"
42	"	Left	403 (2)	90	50	"

(1) Nominal flow rate is .05 lb/sec with 1 engine, .10 lb/sec with both engines.

(2) Run consisted of pulsed flow on a .06 sec on, 1.0 sec off cycle followed by steady state flow.

(3) Run consisted of steady state flow followed by pulsed flow on a .06 sec on, 1.0 sec off cycle.

(4) Run 11 consisted of four pulses for instrumentation checkout, and no data was taken.

3.3 FLOW TEST DATA ACQUISITION

Instrumentation locations are shown on the test schematic, Figure 2-2. The parameters monitored include temperatures, flow, pressure, and differential pressures across all critical test system components. The instrumentation techniques included the recording of all critical parameters on the Leeds and Northrup, Type W strip chart recorder (15)* or the Honeywell Visicorder (11). All temperatures and the feed tank and catch tank pressures were recorded on the strip chart recorder.

The temperature measurements were performed with copper constantan thermocouples with a 150 $\pm$ 0.2°F reference temperature provided by a Pace Reference Junction (16).

The temperature recording system was calibrated periodically with a thermocouple potentiometer to assure proper scale factor. The recorder scale was adjusted to indicate true temperature for operator convenience, but data reduction was performed with the thermoelectric voltage output to provide for the inherent non-linearities of thermocouples.

System component differential pressure measurements were performed with strain-gauge type transducers and signal conditioning units fed to the Visicorder. The engine flow measurements were performed with turbine type meters fed to a pulse rate converter, providing a D.C. voltage proportional to the flow rate. This voltage was also recorded on the Visicorder.

The feed tank and catch tank pressure recording system was calibrated prior to most runs by resistance-pressure ("R-Cal") equivalents to set scale span and zero. "R-Cal" equivalents were determined from transducer calibrations performed by the TRW Systems Group Metrology Laboratory.

Measurement accuracies for each instrument and overall reading are presented in Table 3-2.

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*Number in parenthesis indicates instrumentation list item number in Appendix II.

The above pressure and flow systems were calibrated with internal references immediately preceding each run to assure consistent scale factors. They were also periodically checked immediately following selected runs to monitor short term drifts, if any.

3.3.1 Measurement Accuracy

Table 3-2 presents a tabulation of the uncertainties in temperature, pressure, and flow measurements on an absolute basis and the overall accuracy from run to run.

The "R-Cal" accuracy is a function of the calibration resistor tolerance and allows a constant systematic offset in pressure readout for any given resistor transducer pair.

The maximum within run measurement uncertainties are printed in Table 3-3. This measurement uncertainty is reduced considerably during steady state runs since the repeatability error of the instrumentation becomes negligible.

The uncertainties presented in Tables 3-2 and 3-3 were derived from data supplied by the TRW Metrology Department.

Table 3-2. System Measurement Accuracy Run to Run

Temperature	
Thermocouple	$\pm$ 1.5°F
Recorder ($\pm$ 3% of span, 220°F span)	$\pm$ 0.66°F
Reference Junction	$\pm$ 0.2°F
	$\pm$ 2.4°F
Pressure	
Transducer (linearity + repeatability)	$\pm$ 0.5%
Recorder (resolution of $\pm$ 0.2 div, 65 div)	$\pm$ 0.3%
R-Cal (accuracy of resistors used)	$\pm$ 1.0%
	$\pm$ 1.8%
Flow	
Flowmeter	$\pm$ 0.2%
Rate Converter	$\pm$ 0.2%
Recorder	$\pm$ 0.3%
	$\pm$ 0.7%

Table 3-3. System Measurement Accuracy Within a Single Run

Temperature	
Thermocouple	± 1.5°F
Recorder	± 0.66°F
Reference Junction	± 0.2°F
	± 2.4°F
Pressure	
Transducer (repeatability)	± 0.1%
Recorder	± 0.3%
	± 0.4%
Flow	
Flowmeter	± 0.1%
Recorder	± 0.3%
	± 0.4%

3.4 FLOW TEST CHEMISTRY SUPPORT

The primary function of the program was to observe flow anomalies in the OWPS within the temperature conditions expected in use. Routine specification propellant analyses as well as certain specific chemical analyses were performed to verify that any abnormal flow behavior would be attributable to the system/propellant interface rather than to propellant compositional anomalies alone.

Propellant samples were taken at each temperature set run and analyzed for nitric oxide assay and water equivalent. Non-routine tests such as particulate content, NTO assay, NO assay, chloride content, particle count, metals analysis, infrared analysis, X-ray fluorescence spectra, non volatile residue (NVR) analysis, and nitrate content were performed on selected samples if the run data indicated a spurious result or when fresh propellant was loaded into the run tank.

3.4.1 Analytic Techniques

The analytic techniques for NTO assay, nitric oxide assay, water equivalent, chloride content and particulate content were performed by the procedures outlined in the MSC-PPD-2A specification.

The oxidizer density was measured by weighing the NTO sample in a variable volume pycnometer. The particle size distribution test was adapted from standard particle sizing and counting techniques (References 11 and 12), where the sample is filtered through a cross gridded filter paper and the particles captured are counted under a microscope. The dissolved contaminant test for non-volatile residue (NVR) was conducted by the procedure described in the JPL/NASA Interim Report (Reference 2). This analysis is designed to determine the magnitude of dissolved materials which remain as a residue under conditions of 20 torr, and either 100°C (water solubles) or 60°C (acetone solubles). Although this procedure is not prescribed within any NTO specification, enough data has been accumulated within TRW Systems that it is felt there is a distinct possibility that observed flow anomalies may be attributable to a synergistic effect between the non-volatile contaminant and the postulated colloidal metal content of the propellant (Reference 9).

Dissolved metal content of the oxidizer was determined with a Perkin-Elmer Model 290 atomic absorption spectrometer. Aliquots of each sample (approximately 4 ml) were transferred to glass ampoules. These samples were hydrolyzed in a sulfuric acid-hydrogen peroxide solution which was then concentrated by evaporation and rediluted to a reference volume for analysis. In order to alleviate difficulties associated with transfer of propellant containing insoluble metal-containing species, the transfer was done utilizing a syringe fitted with a Millipore filter holder and a Teflon filter (LCWP-02500, $10 \pm 2\mu$), except for samples Nos. 54, 59, 60 and 64, which were not filtered.

Infrared analyses utilized a Perkin-Elmer Model 521 grating infrared spectrophotometer. The spectra were obtained using either KBr pellet or thin film techniques.

X-ray fluorescence spectra were obtained with a General Electric Model XRD-5 X-ray spectrophotometer.

Nitrate content of aqueous solutions of contaminants were determined by the Brucine alkaloid spectrophotometric procedure.

3.4.2 Experimental Accuracies

Table 3-4 outlines the sensitivity and accuracy of the analytical techniques where applicable. Although the accuracy for atomic absorption analysis is normally quite good, no figures can be given for NTO analyses due to the inherent variations in the sampling and transfer techniques. This problem was emphasized by results from a round robin test on iron content determination by atomic absorption techniques where TRW Systems Group and other aerospace companies analyzed the same solutions of iron compounds at various concentration levels (Reference 13).

Table 3-4. Sensitivity and Accuracy of the Analytical Techniques for Nitrogen Tetroxide Analysis

Accuracy		Sensitivity (low detection limit)	Accuracy
NO Content			$\pm$ 0.005%[1]
Water Equivalent			$\pm$ 0.005%[2]
Chloride Content			$\pm$ 0.005%[1]
Particulate Weight		0.5 mg/l	$\pm$ 0.5 mg/l
Density		-	$\pm$ 0.0005 g/cc
Non-Volatile Residue		0.5 mg/l	$\pm$ 0.5 mg/l
Metals	Fe	0.1 ppm	
	Cu	0.2 ppm	
	Cr	0.2 ppm	
	Ni	0.2 ppm	
	Zn	0.04 ppm	
	Mn	0.1 ppm	
Infrared Spectroscopy		-	qualitative analysis
X-Ray Fluorescence		-	qualitative analysis
Nitrate Content		10 ppm	qualitative analysis

1 Implied by the MSC-PPD-2A Specification Limits

2 $\pm$ .05% Implied by MSC-PPD-2B Specification Limits.

3.5 NITROGEN TETROXIDE AGING STUDIES PROCEDURE

The OWPS will be subjected to thermal cycling during its operating lifetime, therefore, an NTO aging study was performed in order to assess changes in NTO composition which might contribute to performance degradation. Four gallons of NTO, previously stored for approximately six months, were thermally cycled daily for two months between 150°F and 12°F. Chemical analysis of the NTO before cycling showed that it was in specification, with a nominal dissolved metals content. The container was a series 316 stainless steel tank, previously used for NTO storage. The NTO was analyzed after cycling to provide the basis for artificial aging.

3.6 NITROGEN TETROXIDE - BRAZE ALLOY COMPATIBILITY STUDY

A short term compatibility experiment was performed on the braze alloy planned for use in the assembly of the OWPS. Since the test system used in this study was welded and not brazed, it was felt that the test might indicate a potential problem which would not show up on the flow tests. The braze alloy was purchased from Western Gold and Platinum Company as a 4" x 1/2" x 0.010" thick sheet, Nioro VPOF Grade Strip per ASTMB-260-62T Class Bau -4, Lot No. 12456. Lot certification analysis is shown in Table 3-5.

The test was carried out under the same conditions as the NTO aging study; samples of the braze alloy were placed in compatibility tubes, NTO added, and the tubes were thermally cycled between 12°F and 150°F on a once a day cycle for two months.

After the test was completed, the samples were removed from the compatibility tubes and the propellant and samples analyzed.

Table 3-5. Lot Certification Analysis of Braze Alloy Used in the Nitrogen Tetroxide Compatibility Study

Metal	Weight Percent
Gold	81.65
Nickel	18.35
Aluminum	<0.001
Copper	0.004
Lead	0.001
Magnesium	<0.001
Silver	0.008
Iron	0.001
Manganese	<0.001
Silicone	0.001
Palladium	<0.001
Calcium	<0.001

4.0 EXPERIMENTAL RESULTS

Results are in four parts describing the flow test results, the chemical analyses, the braze alloy compatibility results, and the propellant aging results. Each of these contribute to an understanding of the overall system flow decay characteristics. The flow tests give a measure of actual system performance under simulated service conditions while the chemical analyses, compatibility and aging tests give an indication of potential problems due to variations in propellant composition, corrosion of system components, buildup of corrosion products, and possible propellant deterioration.

4.1 FLOW TEST RESULTS

The results of flow testing the system over the expected use temperature range as indicated in the Test Matrix, Table 3-1, are summarized in the plots of percent corrected flow vs. time presented in Figures 4-1 through 4-40. More detailed data as to pressure drops, temperatures and actual flow for each component showing significant flow anomalies is presented in the plots of Appendix IV and the tabulations of Appendix V. The corrected flow values presented were obtained by calculating an equivalent flow area for each component based on the pressure drop, flow rate, and temperature at that location and then calculating the equivalent flow based on a standard pressure drop and temperature.

Both the corrected flow and equivalent area calculation were based on the relation:

$$Q = C_d A \sqrt{2gh} \qquad (1)$$

where: Q = volumetric flow

g = acceleration due to gravity

h = head loss

A = area

C_d = discharge coefficient - dimensionless taken as .6 in all calculations.

The above equation is just a special case of Bernoulli's equation:

$$\frac{1}{2g}\left(V_2^{\,2} - V_1^{\,2}\right) + \frac{P_2 - P_1}{\rho} + (H_2 - H_1) = 0 \qquad (2)$$

where: V = flow velocity

P = pressure

ρ = weight density

H = head

g = acceleration due to gravity

and the subscripts 1 and 2 refer to the conditions at the inlet and outlet to the component.

Rearranging (1), the calculated flow area is:

$$A = \frac{Q}{C_d\sqrt{2gh}} \qquad (3)$$

where:

$$h = \frac{(P_1 - P_2)}{\rho} \qquad (4)$$

The volumetric flow and propellant temperature were determined from the flow meter and thermocouple located downstream of each engine. This volumetric flow was converted to weight flow at the measured temperature according to the relation

$$w = Q\rho \qquad (5)$$

where: w = weight flow.

By continuity the mass or weight flow in the system must be a constant and therefore this weight flow calculated from each flow meter was used in calculating the data for its corresponding engine, and the weight flows from the two flow paths were summed to obtain the total flow through the isolation valves and filters. Local volumetric flows were calculated for each component from the mass flow using the density indicated by the inlet temperature to the component from equation (5) rearranged to read:

$$Q = \frac{W}{\rho} \tag{6}$$

These actual volumetric flows were used to calculate the equivalent flow areas for each component from equation (3).

Corrected flow data as presented in Appendix III was obtained by calculating volumetric flow from equation (1) and weight flow from equation (5) at a pressure drop of 120 psi for the engines, 8 psi for one isolation valve open, and 2 psi for two isolation valves open. The temperature was taken as 70°F in all corrected flow calculations. The values of pressure drop for the corrected flow calculations were selected from the engine data in Appendix I and the actual pressure drop data generated in system testing as presented in Appendix V.

It should be noted that the percent of "maximum corrected flow" data is numerically equal to percent of "maximum equivalent area" data thus giving an indication of percentage variation in flow and/or equivalent orifice size in the same plots. The actual corrected flows and equivalent areas for each condition may be calculated by multiplying the percent indicated by the maximum flow or the maximum equivalent area. The data used to prepare these plots including corrected flow data is presented in tabular form in Appendix III. The maximum flow and equivalent areas for the components showing significant flow variations during the test program are shown in Table 4-1.

The occurrences in which observed flows through a component or the system did not correspond to expected behavior for a normal liquid flow system have been classed as flow anomalies or flow variations and flow decays or flow degradations. Flow anomalies or variations include any abnormal flow behavior such as abrupt or gradual increases and decreases in flow or a combination of these over a flow run. Flow decays or degradations indicate a continuous flow decrease over a portion of a flow run as opposed to the more general case of the flow anomalie or variation.

Table 4-1

Component	Max. Equiv. Area (in^2)	Max. Corrected Flow Lb/Sec	Max. Corrected Flow GPM	Run No.
Right Engine	1.310×10^{-3}	.0547	.272	19
Left Engine	1.371×10^{-3}	.0572	.285	37
Both Isolation Valves	19.75×10^{-3}	.106	.530	9
Right Isolation Valve	10.59×10^{-3}	.114	.568	32
Left Isolation Valve	10.08×10^{-3}	.109	.541	37

It can be seen from examining Figures 4-1 through 4-40 that flow variations of up to 14.6 percent and 15.8 percent were experienced by the right and left engines, respectively. The isolation valves showed a 21.5 percent variation. The most serious case of flow decay occurred during run 7 for the engines and run 5 for the isolation valves (both open). The temperature conditions for runs 7 and 5 were a feed tank temperature of 150°F and a system temperature of 12°F. The right engine flowed slightly less than the left in most runs on an actual flow basis (see Appendices IV and V), however, it stayed above the left engine in a majority of runs on a percentage basis. This indicates an unequal susceptibility to flow degradation or decay for the two engines and a possible slight initial mismatch in equivalent orifice size. The left isolation valve showed a higher flow variation than the right, however, it was normally used during the steady-state followed by pulse runs, while the right isolation valve was used more frequently for the pulse followed by steady-state runs. The left isolation valve showed the greatest percent corrected flow degradation which was 8.6 percent and occurred during run 31. The right isolation valve exhibited maximum corrected flow degradation of 3.3 percent during run 32. Table 4-2 summarizes the occurrences of flow anomalies, and flow decay for each run. Temperature conditions and percent of maximum flows for each component are also included.

Table 4-2. Test Result

Run	Temp °F		Max Percent Corrected Flow					Max Percent Flow Variation					Max Percent Flow Decay					Propellant	Run Con
	Feed Tank	System	Rt Eng	Lt Eng	Both Iso	Rt Iso	Lt Iso	Rt Eng	Lt Eng	Both Iso	Rt Iso	Lt Iso	Rt Eng	Lt Eng	Both Iso	Rt Iso	Lt Iso		
2	150	150	78.4	93.0	86.0	-	-	14.6	10.2	21.5	-	-	-	2.6	15.6	-	-	NASA MSC PPD-2 Propellant	
3	150	75	79.8	92.7	78.3	-	-	1.2	7.0	7.6	-	-	1.2	6.2	6.3	-	-		
4	150	75	-	90.3	74.2	-	-	-	5.8	4.0	-	-	-	5.8	3.2	-	-		Stea
5	150	12	-	97.6	82.7	-	-	-	1.3	15.2	-	-	-	11.3	15.2	-	-		Stat
6	150	12	80.6	-	70.9	-	-	3.6	-	7.6	-	-	3.6	-	7.5	-	-		Flow
7	150	12	85.4	99.3	81.3	-	-	13.4	15.8	11.0	-	-	5.9	15.8	2.8	-	-		
8	58	58	93.8	88.6	96.6	-	-	0.7	0.3	0.6	-	-	0.3	0.4	0.6	-	-		
9	70	60	95.4	90.7	100.0	-	-	1.8	0.4	4.0	-	-	1.8	0.3	4.0	-	-		1
10	70	60	91.9	87.6	88.9	-	-	0.1	0.2	0.6	-	-	0.1	0.1	0.6	-	-		2
12	70	50	95.4	90.3	97.0	-	-	1.1	1.1	2.8	-	-	0.7	0.4	1.0	-	-		1
13	70	50	94.4	89.9	92.0	-	-	1.4	1.4	1.1	-	-	1.4	0.4	1.1	-	-		2
14	90	50	95.7	90.0	91.2	-	-	2.7	1.9	1.5	-	-	2.7	2.0	0.5	-	-		1
15	90	50	93.2	90.3	-	95.0	-	1.4	2.3	-	3.9	-	0	2.3	-	3.2	-		2
16	12	150	94.9	95.3	-	66.3	-	4.6	2.5	-	2.0	-	4.6	2.5	-	2.0	-		Puls
17	12	150	93.4	95.4	-	-	79.5	5.5	11.2	-	-	4.6	5.1	1.2	-	-	4.2		Steady
18	12	12	94.3	92.3	-	91.1	-	2.5	1.2	-	1.9	-	2.2	0.6	-	1.6	-		2
19	12	12	100.0	89.9	-	-	92.0	3.4	0.7	-	-	1.3	3.4	0.6	-	-	1.0		1
20	90	90	90.1	91.3	-	88.9	-	2.6	2.7	-	1.0	-	0.1	1.9	-	0	-		2
21	90	90	91.2	90.1	-	-	92.7	2.3	0.8	-	-	2.3	1.2	0.1	-	-	2.3		1
22	70	70	92.7	90.9	-	93.3	-	0.9	1.7	-	1.8	-	1.0	0.7	-	1.8	-		2
23	70	70	92.0	89.9	-	-	94.0	1.0	0.6	-	-	0.9	0.6	0.6	-	-	0.9		1
24	50	50	94.3	92.2	-	94.9	-	2.6	2.7	-	2.5	-	1.6	2.0	-	2.4	-		2
25	50	50	95.5	90.7	-	-	96.4	1.0	0.5	-	-	2.1	0.7	0.5	-	-	2.2		1
26	30	30	92.7	90.9	-	93.9	-	1.1	2.2	-	1.0	-	1.1	2.1	-	1.0	-		1
27	30	30	93.2	89.4	-	-	95.0	4.1	0.6	-	-	1.4	4.1	0.5	-	-	1.5		2
28	30	30	93.7	90.6	90.3	-	-	0.3	1.0	6.7	-	-	0.3	0.7	6.7	-	-		Ste
29	90	70	93.8	98.0	-	-	94.6	4.3	7.3	-	-	4.0	3.3	1.9	-	-	2.2		2
30	90	70	94.1	97.0	-	96.3	-	2.7	8.2	-	5.6	-	0.5	1.8	-	1.4	-		1
31	90	50	95.6	98.8	-	-	97.4	2.2	9.7	-	-	8.5	2.0	9.7	-	-	8.6		2
32	90	50	96.0	97.4	-	100.0	-	2.9	7.9	-	3.7	-	2.2	4.0	-	3.3	-		1
33	90	90	93.0	89.1	-	-	88.6	0.4	0.4	-	-	0.7	0.4	0.4	-	-	0.7	Artificially Aged Propellant	1
34	90	90	93.1	89.0	-	90.7	-	0.8	0.4	-	1.5	-	0.9	0.4	-	1.5	-		2
35	70	70	93.8	88.7	-	-	90.7	1.2	0.2	-	-	0.6	0.8	0.2	-	-	0.4		1
36	70	70	93.6	88.1	-	91.8	-	1.2	0.2	-	1.4	-	1.2	0.3	-	1.4	-		2
37	50	50	95.6	100.0	-	-	100.0	0.5	11.2	-	-	6.2	0.2	4.3	-	-	2.2		1
38	50	50	95.9	98.6	-	95.8	-	1.1	3.5	-	2.0	-	0.9	3.2	-	2.0	-		2
39	90	70	94.0	89.7	-	-	91.4	0.9	0.4	-	-	1.8	0.6	0.2	-	-	0.9		1
40	90	70	93.9	89.1	-	91.8	-	0.6	0.6	-	0.6	-	0.5	0.5	-	0.5	-		2
41	90	50	97.6	89.8	-	-	94.5	2.2	0.6	-	-	4.3	2.2	0.3	-	-	4.3		1
42	90	50	94.3	90.4	-	95.4	-	1.0	0.8	-	2.3	-	0.9	0.8	-	1.6	-		2

(1) Run consisted of steady state flow followed by pulsed flow on a .06 sec on, 1.0 sec off cycle.

(2) Run consisted of pulsed flow on a .06 sec on, 1.0 sec off cycle followed by steady state flow.

4.1.1 Experimental Data Reduction Uncertainty

The equivalent area of each component was calculated from the equation, obtained by combining equations (3) through (5).

$$A = \frac{Q\rho_1}{C_d \rho_2 \sqrt{2g \frac{\Delta P}{\rho_2}}} \tag{7}$$

where: Q = volumetric flow at flowmeter

ρ_1 = weight density at flowmeter

ρ_2 = weight density at component

ΔP = component differential pressure

C_d = discharge coefficient

g = acceleration due to gravity

Rearranging (7)

$$A = KQ\rho_1 \rho_2^{-1/2} \Delta P^{-1/2} \tag{8}$$

where: $K = \frac{1}{C_d \sqrt{2g}}$

The density was determined from the formula:

$$\rho = 95.4 - 0.0737T - 2.65 \times 10^{-9} \times T^4 \tag{9}$$

where: T = temperature °F

This equation was selected for a precise fit to the density curve provided in Reference 15. The total uncertainty in density is

$$\Delta\rho = \frac{\partial\rho}{\partial T} \Delta T \tag{10}$$

The worst case density error is at 150°F where $\Delta\rho = 0.29\%$.

The error in equivalent area is given by:

$$\Delta A = \frac{\partial A}{\partial Q}\Delta Q + \frac{\partial A}{\partial \rho_1}\Delta\rho_1 + \frac{\partial A}{\partial \rho_2}\Delta\rho_2 + \frac{\partial A}{\partial \Delta P}\Delta(\Delta P) \qquad (11)$$

The individual errors are:

$$\frac{\partial A}{\partial Q}\Delta Q = K\rho_1\rho_2^{-1/2}\,\Delta P^{-1/2}\,\Delta Q \qquad (12)$$

$$\frac{\partial A}{\partial \rho_1}\Delta\rho_1 = KQ\rho_2^{-1/2}\,\Delta P^{-1/2}\,\Delta\rho_1 \qquad (13)$$

$$\frac{\partial A}{\partial \rho_2}\Delta\rho_2 = \frac{1}{2}KQ\rho_1\rho_2^{-3/2}\,\Delta P^{-1/2}\,\Delta\rho_2 \qquad (14)$$

$$\frac{\partial A}{\partial \Delta P} = \frac{1}{2}KQ\rho_1\rho_2^{-1/2}\,\Delta P^{-3/2}\,\Delta(\Delta P) \qquad (15)$$

Substituting equations (12) through (15) in equation (11), and dividing by equation (8), the percent error in equivalent area is given by:

$$\frac{\Delta A}{A}100 = \left(\frac{\Delta Q}{Q} + \frac{\Delta\rho_1}{\rho_1} + \frac{\Delta\rho_2}{2\rho_2} + \frac{\Delta(\Delta P)}{2\Delta P}\right)100 \qquad (16)$$

Substituting the values from Table 3-2 in equations (10) and (16), the absolute and run to run accuracy is given by:

$$(100)\frac{\Delta Q}{Q} = \pm 0.7\%$$

$$(100)\frac{\Delta\rho_1}{\rho_1} = 0.29\%$$

$$100\left(\frac{1}{2}\right)\left(\frac{\Delta\rho_2}{\rho_2}\right) = .14\%$$

$$100\left(\frac{1}{2}\right)\left(\frac{\Delta(\Delta P)}{\Delta P}\right) = .9\%$$

The total uncertainty in equivalent area on a run to run basis from equation (16) is ± 2.0 percent.

The within-run uncertainty is obtained in similar fashion by substituting the values from Table 3-3 in equations (10) and (16). The within-run uncertainty in equivalent area is ± 1.0 percent. Since corrected flow data was calculated at an arbitrary pressure and density condition, no further error is introduced compared to the equivalent area.

4.1.2 Result Summary

The within-run accuracy in the corrected flow from Section 3.3 and 4.4.1 is ± 1.0 percent, resulting in a two percent flow uncertainty band. Therefore, a flow decay of two percent was chosen as the minimum significant value. In twenty-four out of forty runs, flow decays equal to or greater than two percent were experienced in the engines and/or the isolation valves. Figures 4-41 through 4-45 illustrate the percent maximum flow variation as a function of feed tank and OWPS temperature, and Figures 4-46 through 4-50 illustrate the percent maximum flow decay as a function of feed tank and OWPS temperature.

In order to assess the possible effects of the operational mode on flow degradation, plots of maximum percent flow decay versus feed tank and OWPS temperature were made for the right and left engines. Separate curves are shown for steady-state-pulse operation and pulse-steady-state operation. These plots are presented in Figures 4-51 through 4-54.

In general, the largest flow anomalies and decays occurred at the temperature extremes, 150°F and 12°F. The flow variations were greatest for the left engine and isolation valves. Most variations occurred during the initial portion of the run, or when the run mode was switched, e.g., from pulse to steady-state or vice versa.

In most cases where there was an initial feed tank to OWPS temperature gradient, the flow decay was greater when the system was operated in the pulse-steady-state mode. This operating mode allowed the initial temperature gradient to exist for a longer period than the steady-state-pulse mode since the system tended to be heated or cooled by the incoming propellant.

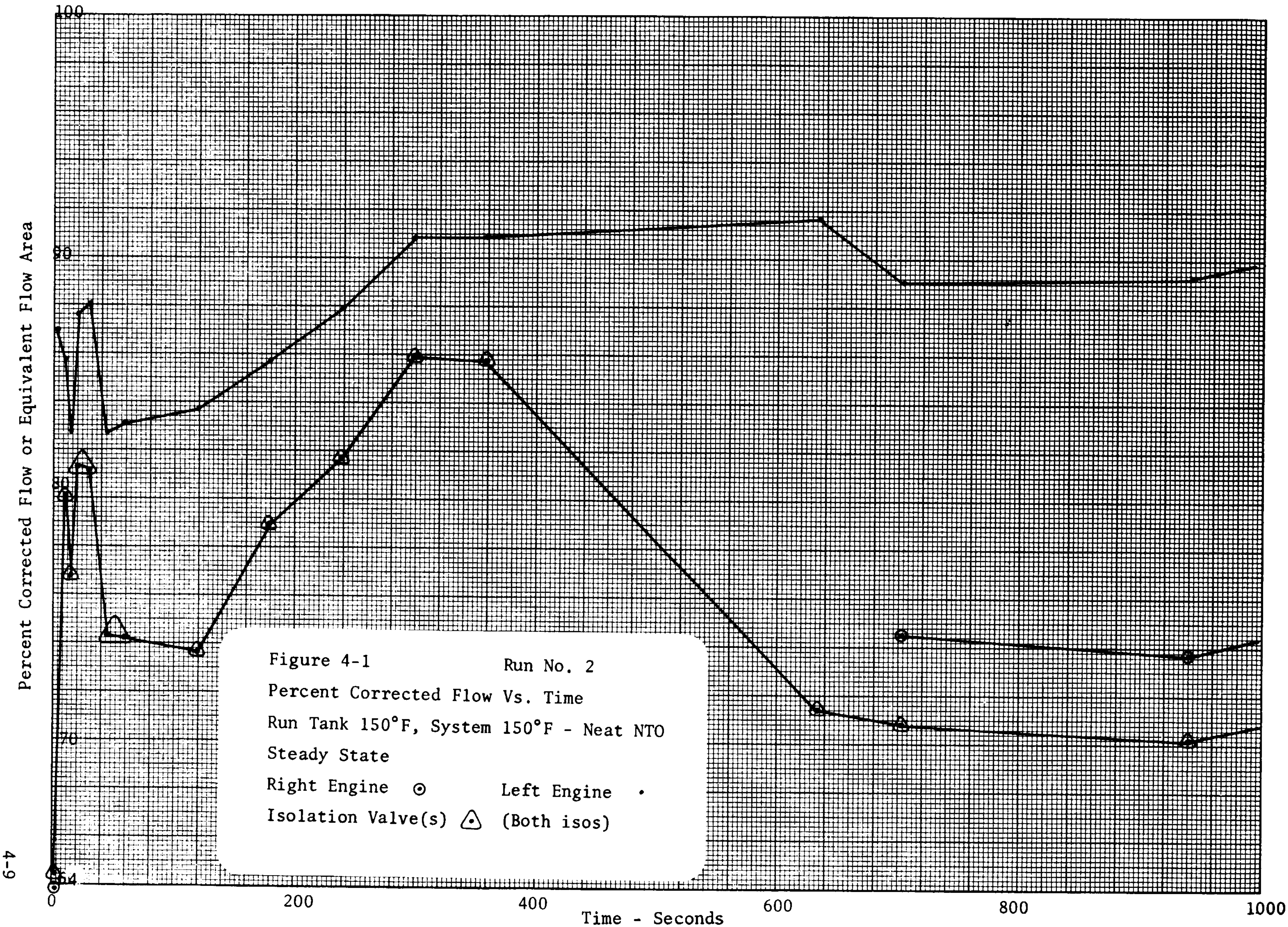


Figure 4-1 Run No. 2

Percent Corrected Flow Vs. Time

Run Tank 150°F, System 150°F - Neat NTO

Steady State

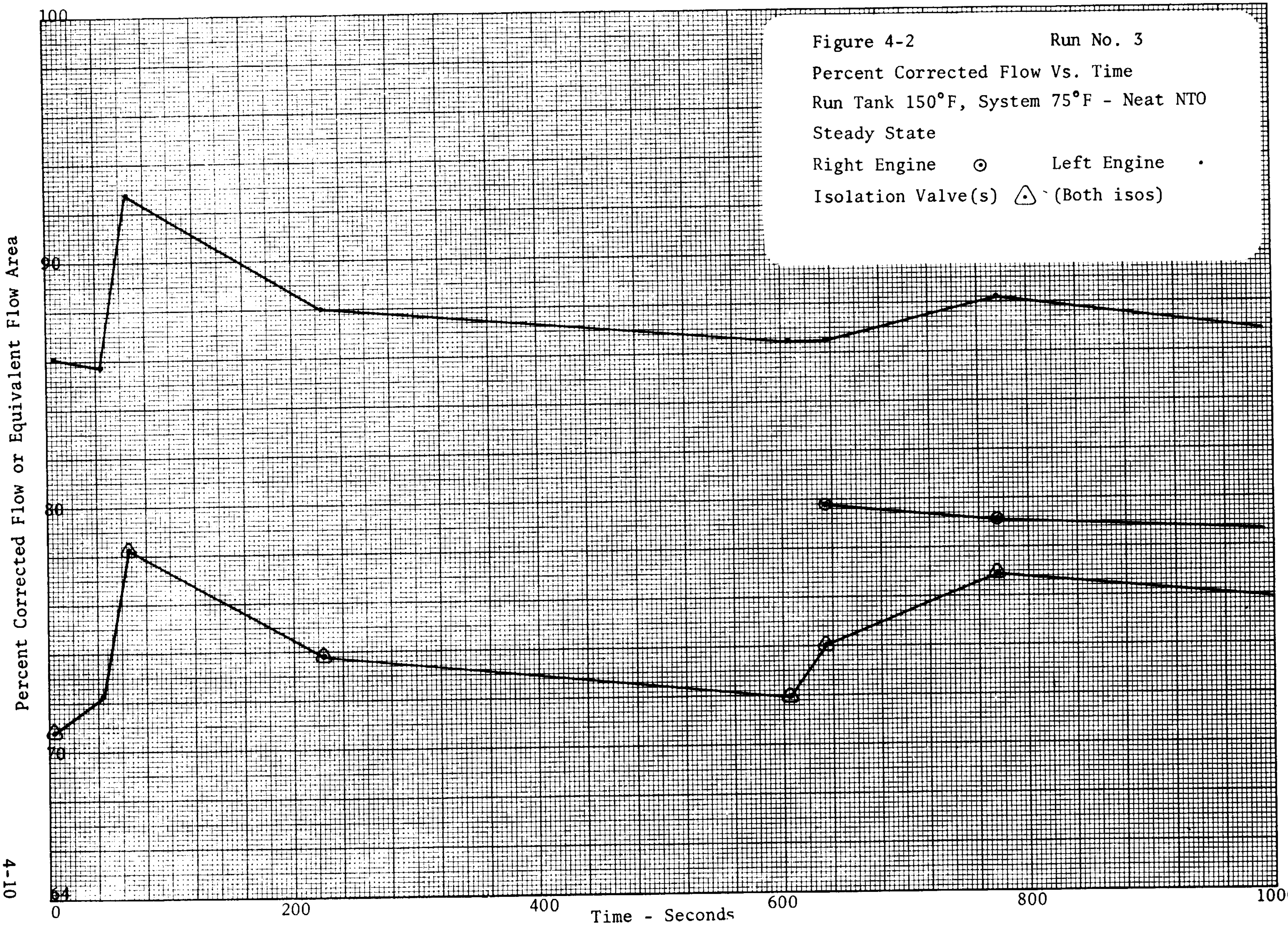


Figure 4-2
Run No. 3
Percent Corrected Flow Vs. Time
Run Tank 150°F, System 75°F - Neat NTO
Steady State
Right Engine ⊙
Left Engine •
Isolation Valve(s) (Both isos)
Percent Corrected Flow or Equivalent Flow Area
100
90
80
70
64
0
200
400
600
800
1000
Time - Seconds

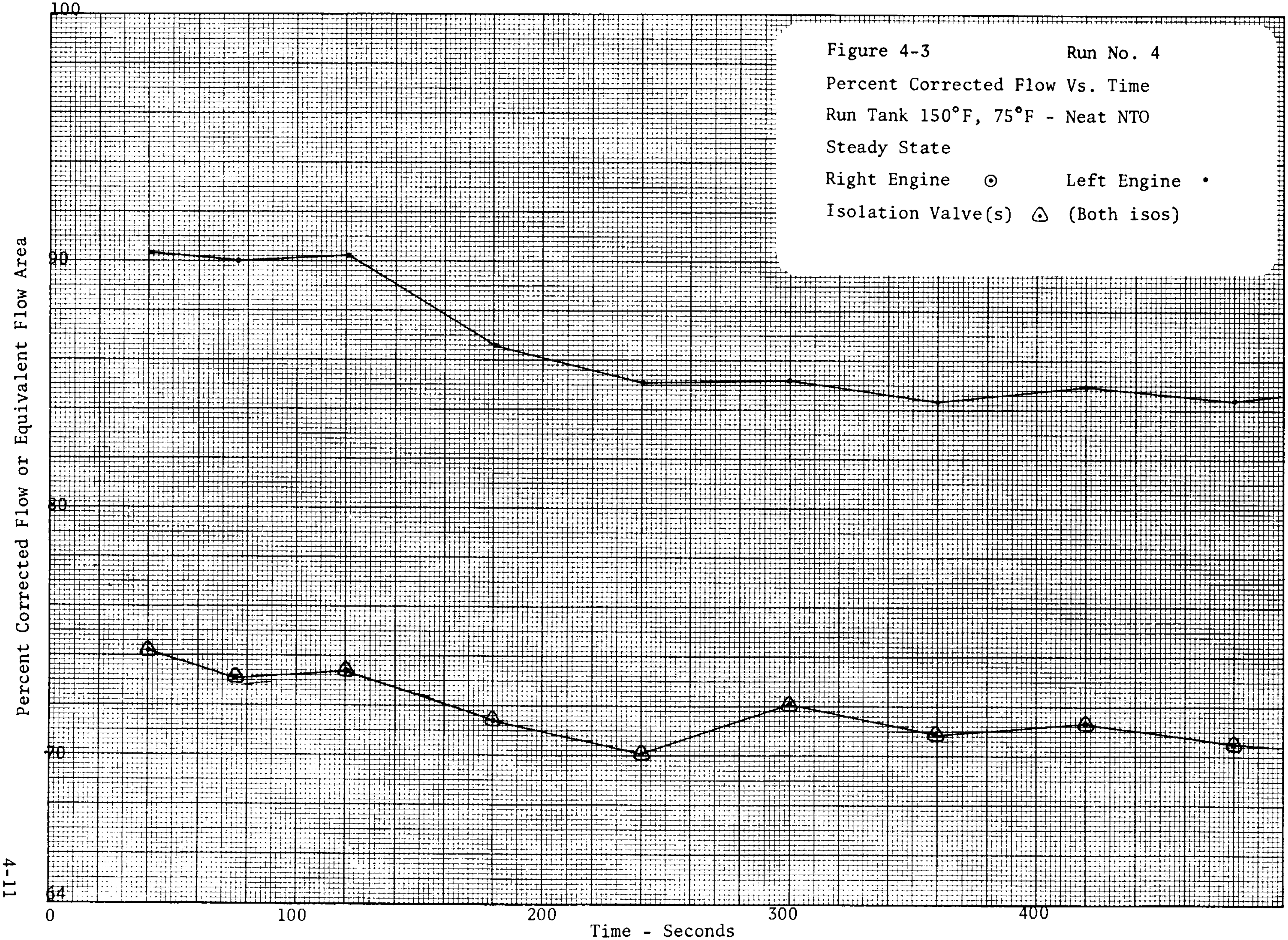


Figure 4-3
Run No. 4
Percent Corrected Flow Vs. Time
Run Tank 150°F, 75°F - Neat NTO
Steady State
Right Engine ⊙
Left Engine •
Isolation Valve(s) △ (Both isos)
100
90
80
70
64
0
100
200
300
400
Time - Seconds
Percent Corrected Flow or Equivalent Flow Area

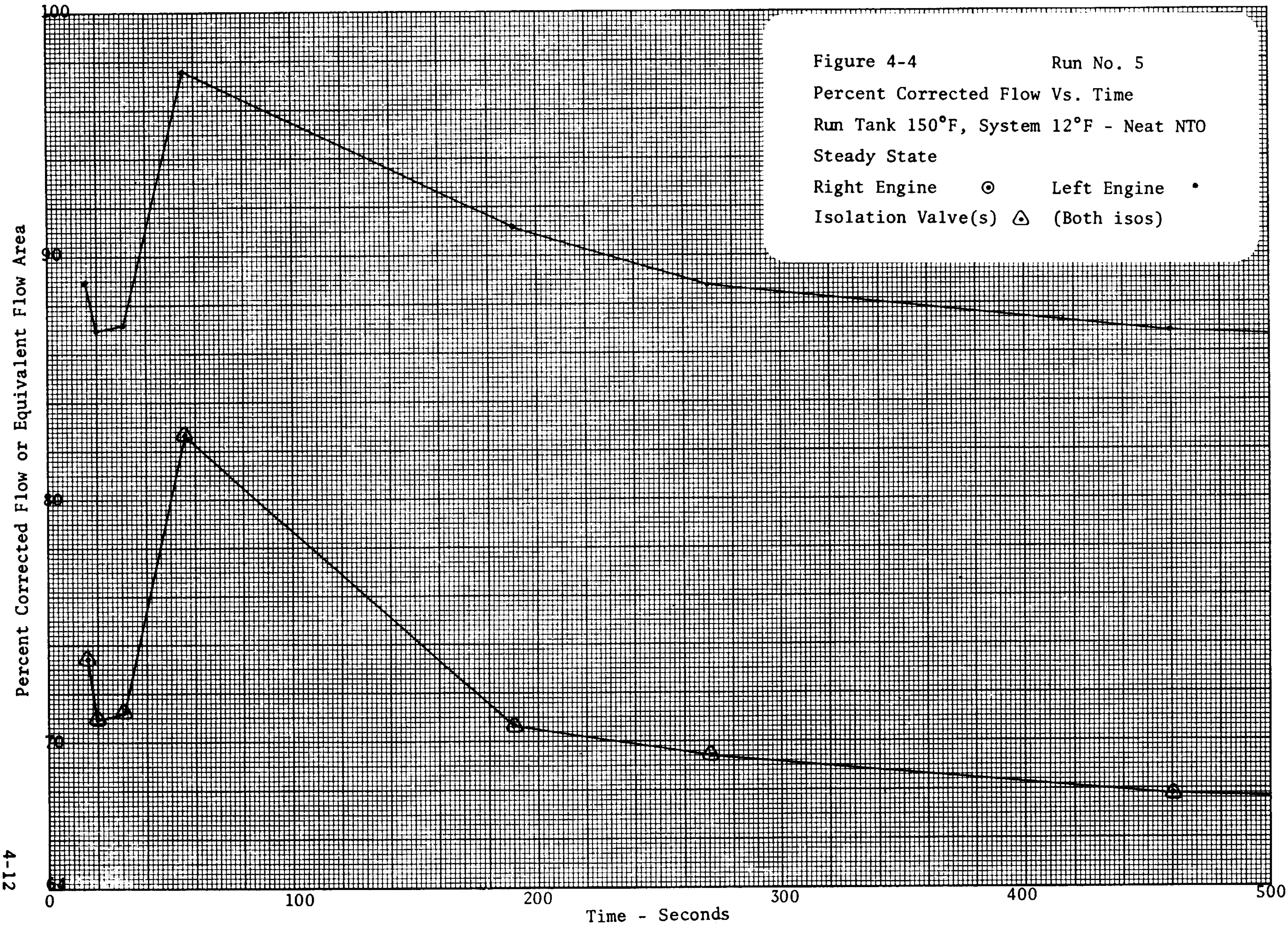


Figure 4-4
Run No. 5
Percent Corrected Flow Vs. Time
Run Tank 150°F, System 12°F - Neat NTO
Steady State
Right Engine ⊙
Left Engine •
Isolation Valve(s) △ (Both isos)
Percent Corrected Flow or Equivalent Flow Area
100
90
80
70
0
100
200
300
400
500
Time - Seconds

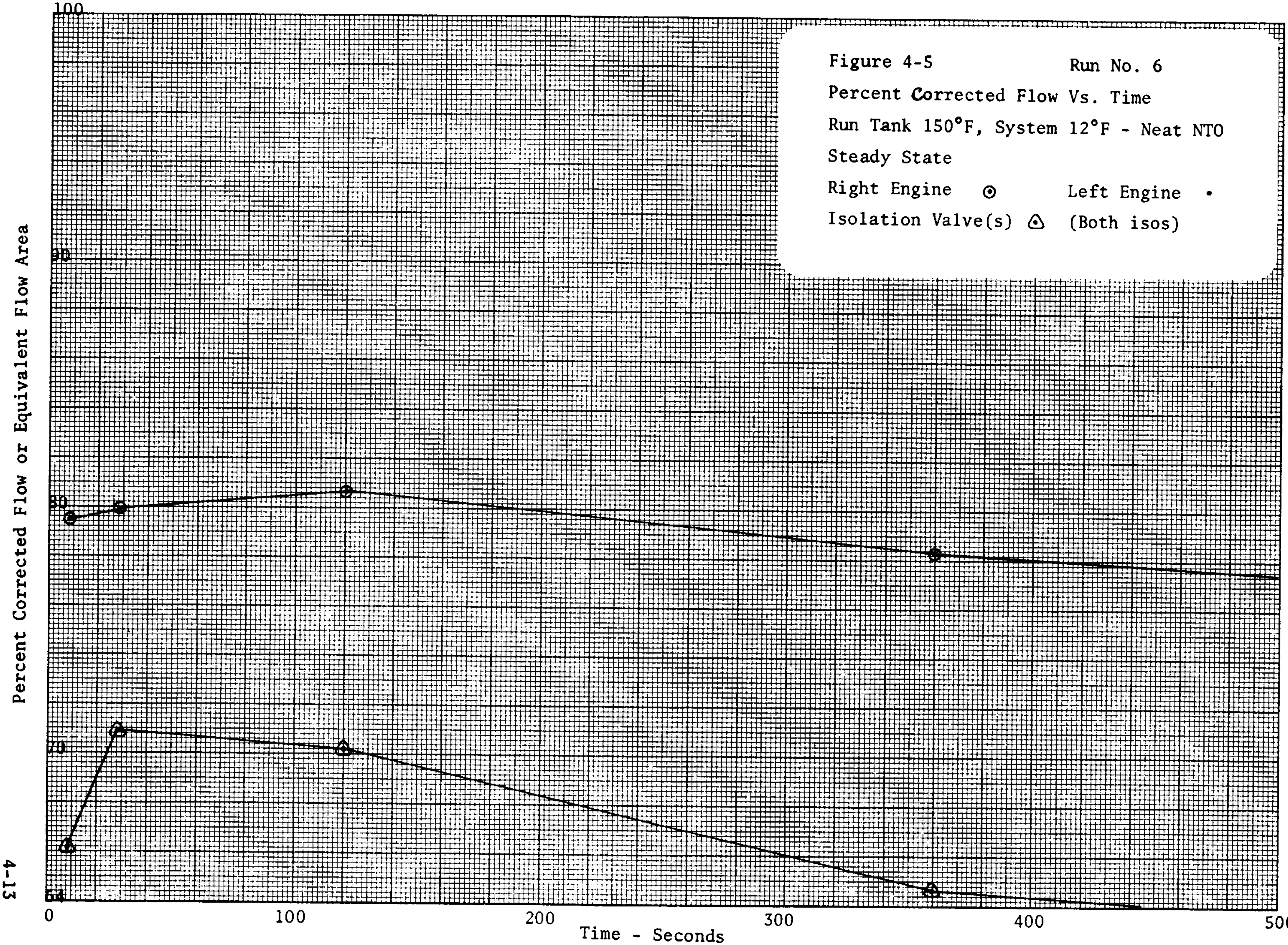


Figure 4-5
Run No. 6
Percent Corrected Flow Vs. Time
Run Tank 150°F, System 12°F - Neat NTO
Steady State
Right Engine ⊙
Left Engine •
Isolation Valve(s) △
(Both isos)
100
90
80
70
64
0
100
200
300
400
500
Time - Seconds
Percent Corrected Flow or Equivalent Flow Area

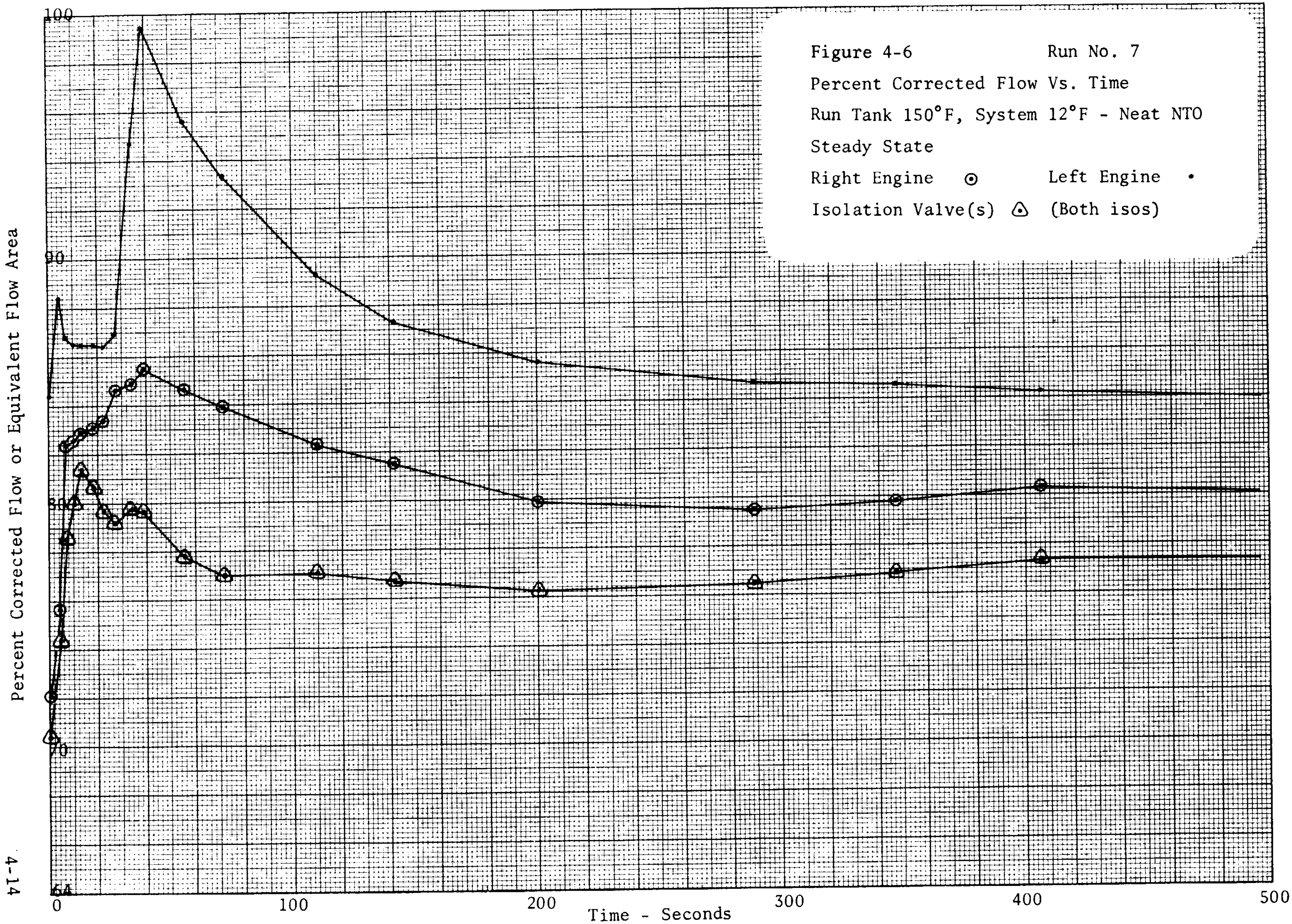


Figure 4-6
Run No. 7
Percent Corrected Flow Vs. Time
Run Tank 150°F, System 12°F - Neat NTO
Steady State
Right Engine ⊙
Left Engine •
Isolation Valve(s) (Both isos)
Percent Corrected Flow or Equivalent Flow Area
100
90
80
70
64
0
100
200
300
400
500
Time - Seconds

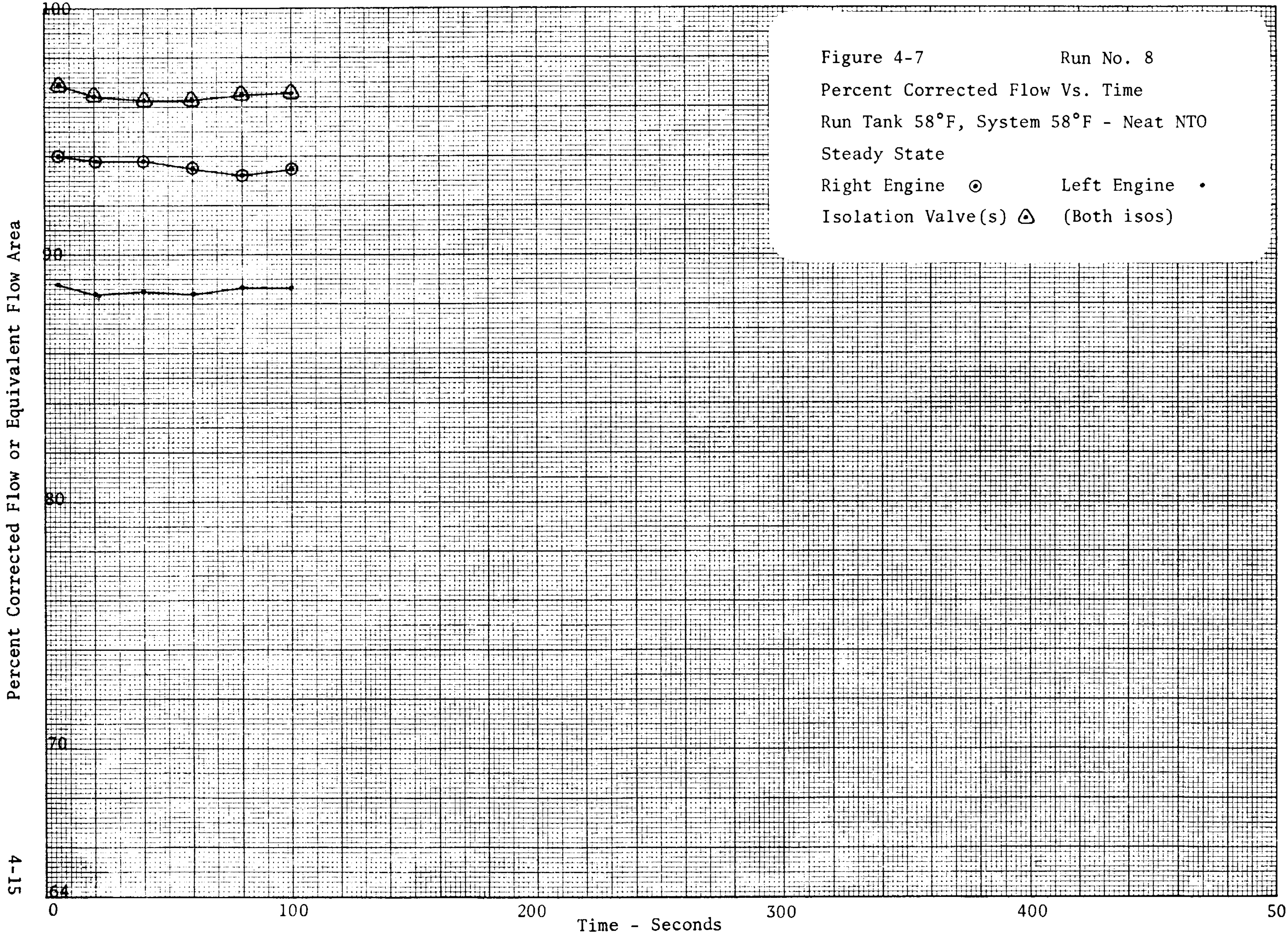
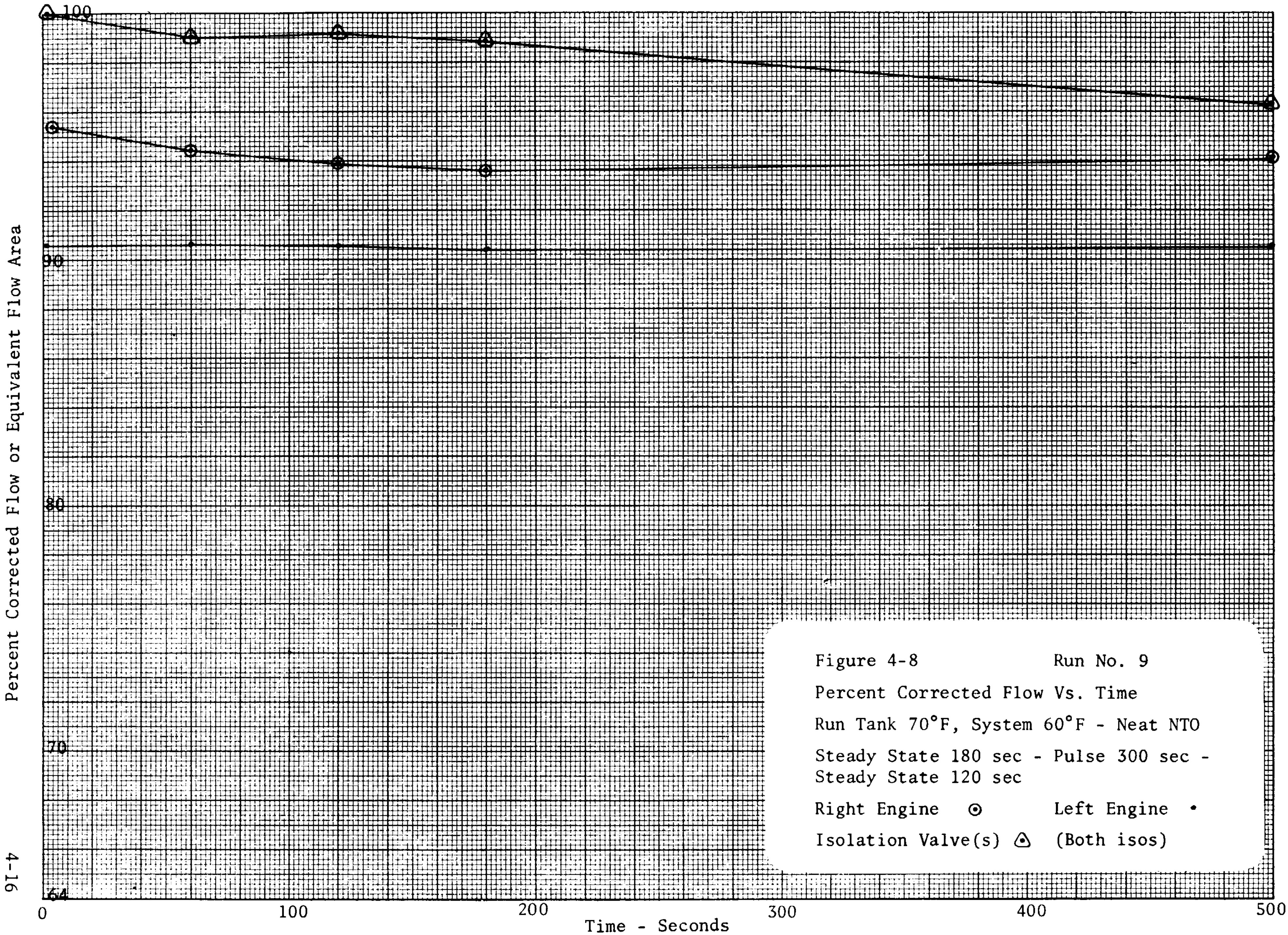


Figure 4-7 Run No. 8
Percent Corrected Flow Vs. Time
Run Tank 58°F, System 58°F - Neat NTO
Steady State
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Both isos)
Percent Corrected Flow or Equivalent Flow Area
100
90
80
70
64
0
100
200
300
400
500
Time - Seconds


Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
100
90
80
70
64
0
100
200
300
400
500
Figure 4-8
Run No. 9
Percent Corrected Flow Vs. Time
Run Tank 70°F, System 60°F - Neat NTO
Steady State 180 sec - Pulse 300 sec - Steady State 120 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) △
(Both isos)

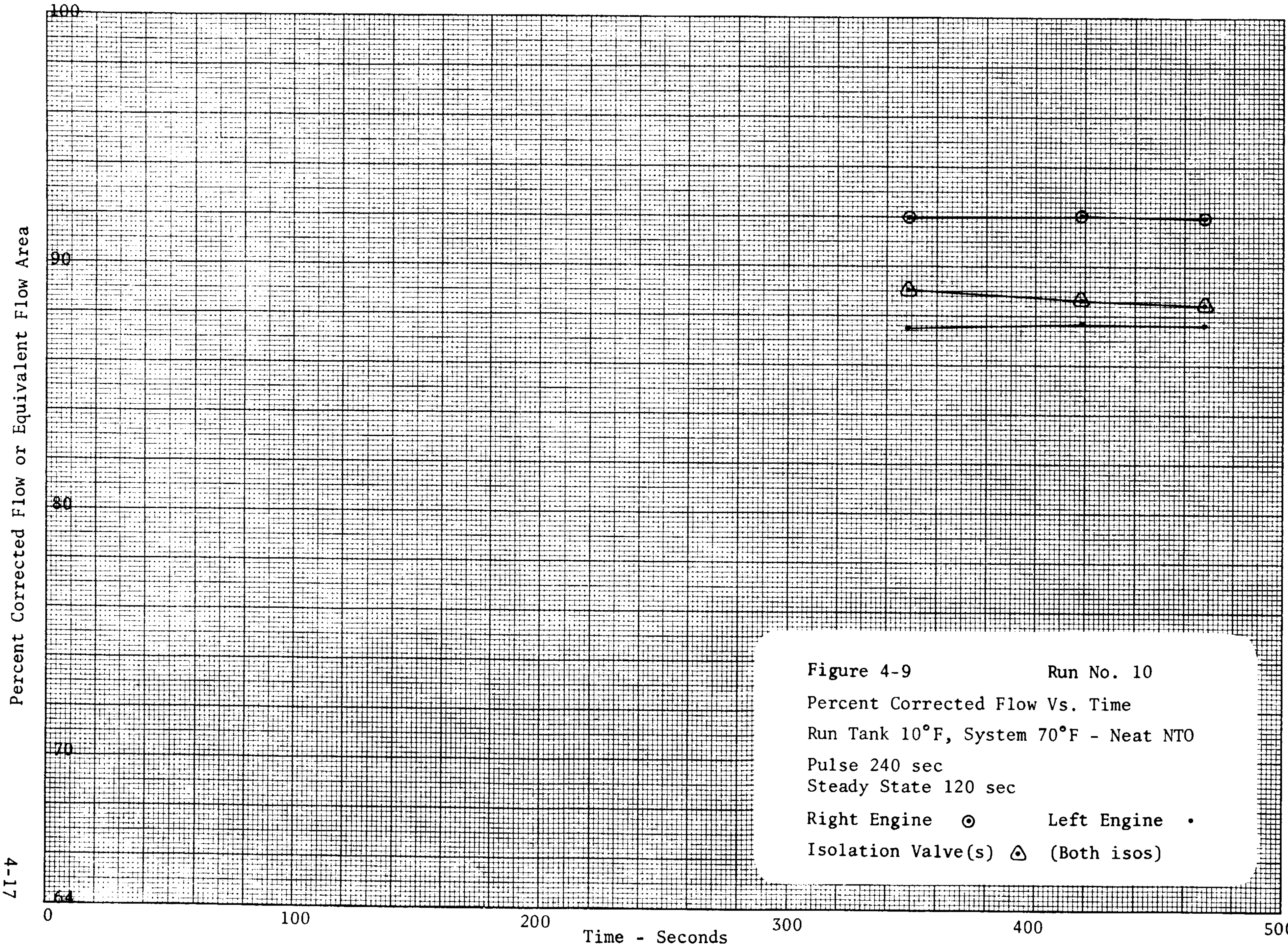


Figure 4-9 Run No. 10

Percent Corrected Flow Vs. Time

Run Tank 10°F, System 70°F - Neat NTO

Pulse 240 sec
Steady State 120 sec

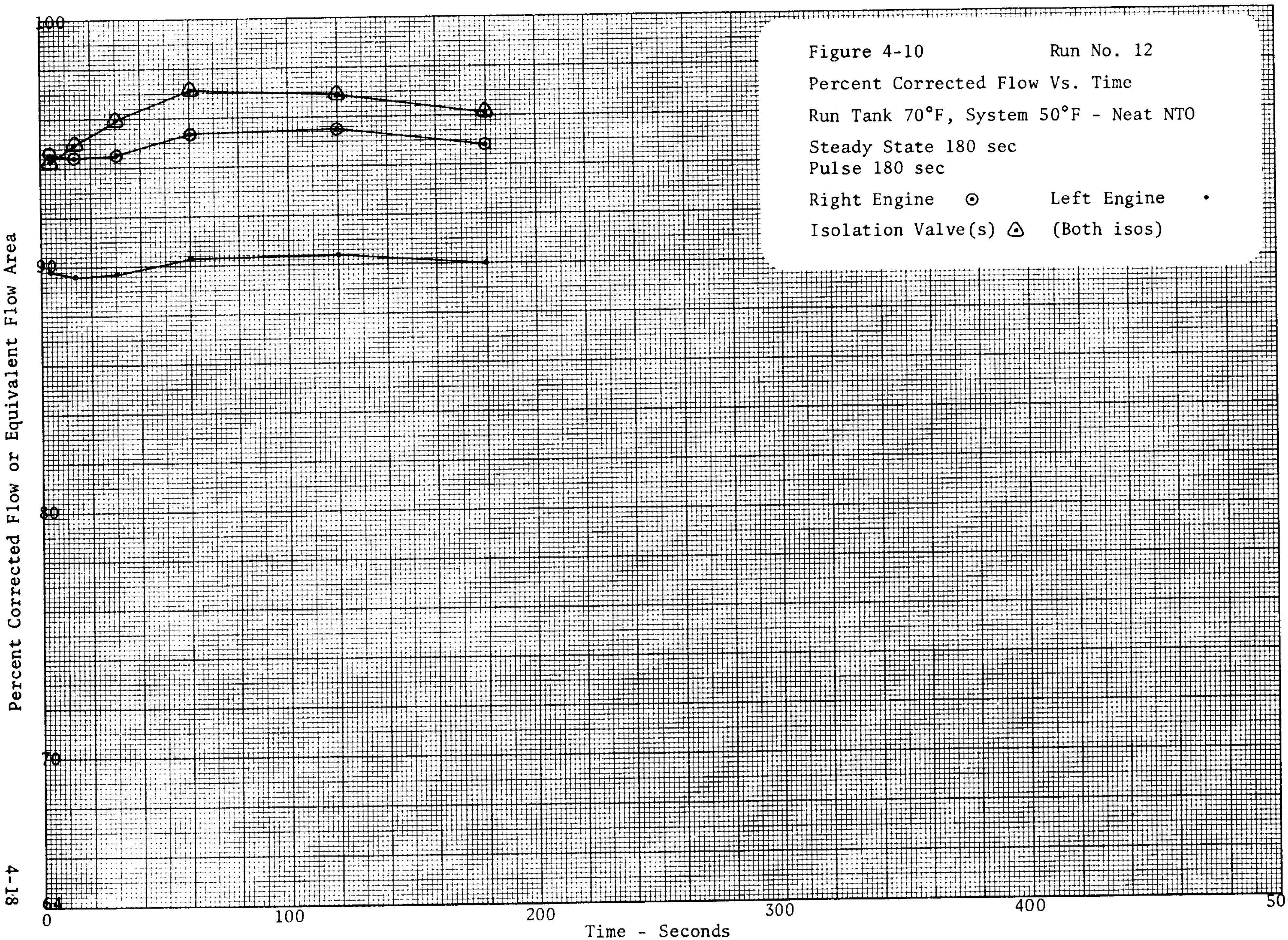
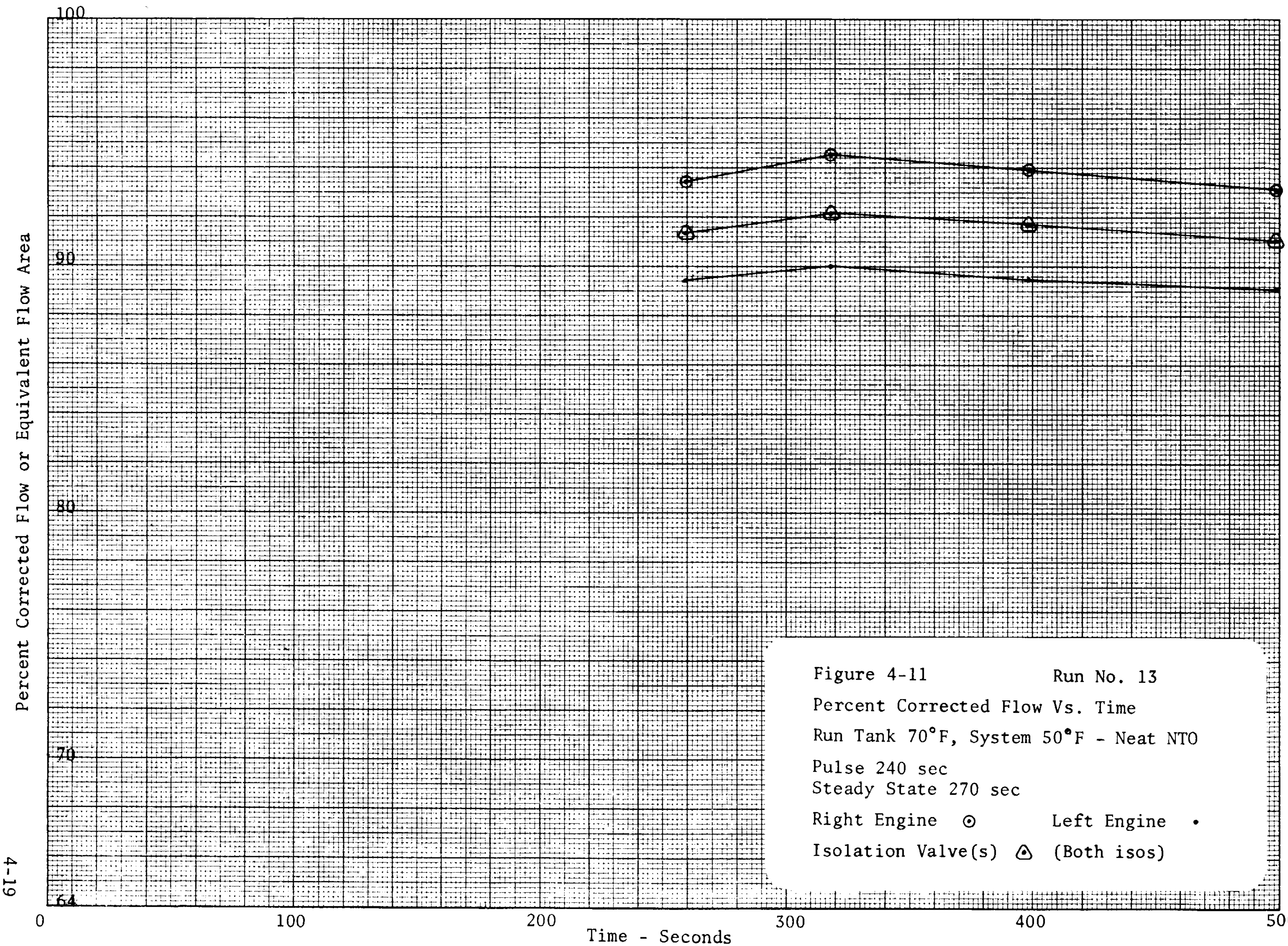


Figure 4-10
Run No. 12
Percent Corrected Flow Vs. Time
Run Tank 70°F, System 50°F - Neat NTO
Steady State 180 sec
Pulse 180 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) △
(Both isos)
100
90
80
70
64
0
100
200
300
400
500
Time - Seconds
Percent Corrected Flow or Equivalent Flow Area



100
90
80
70
64
0
100
200
300
400
500
Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
Figure 4-11
Run No. 13
Percent Corrected Flow Vs. Time
Run Tank 70°F, System 50°F - Neat NTO
Pulse 240 sec
Steady State 270 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s)
(Both isos)

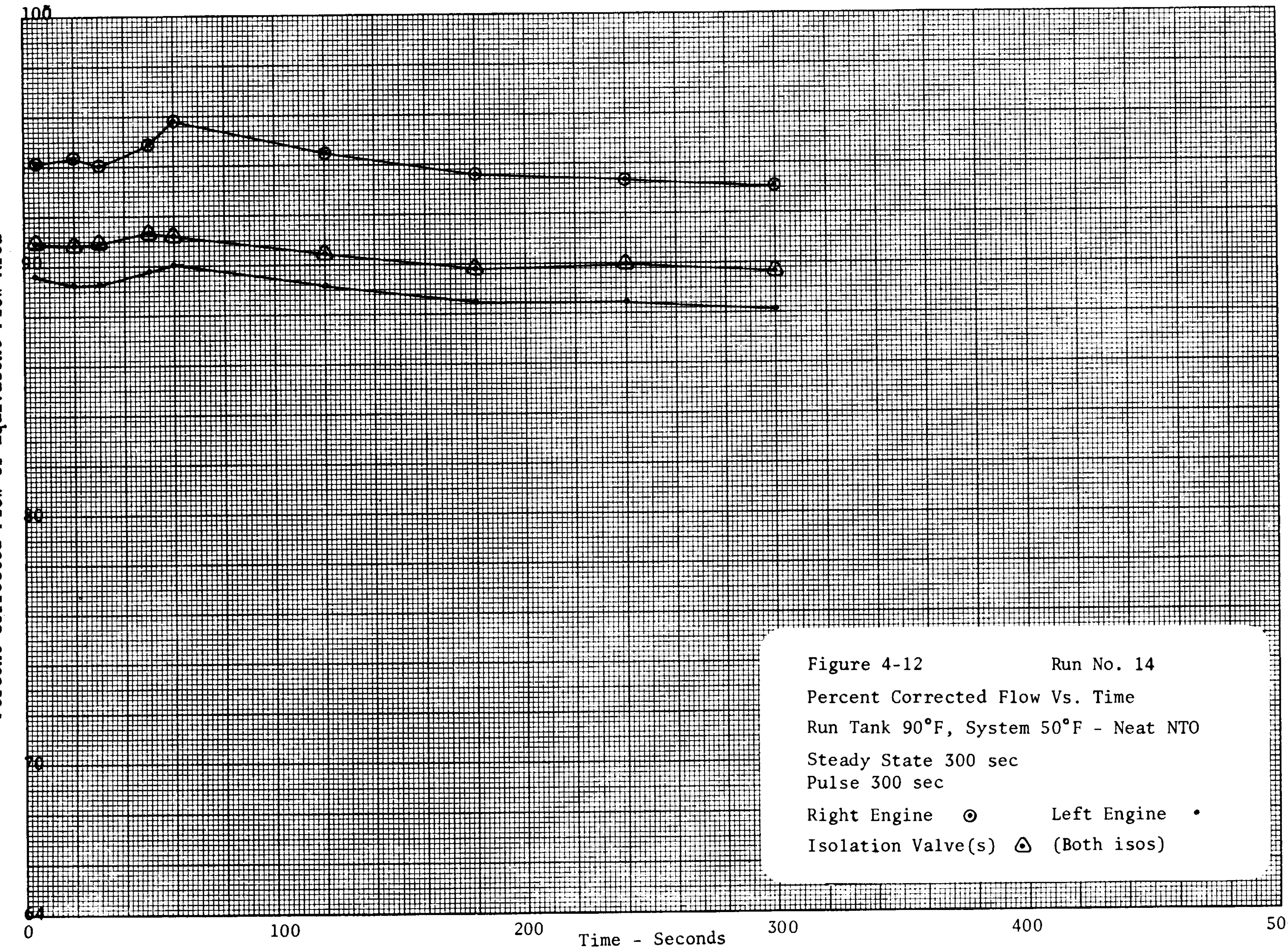
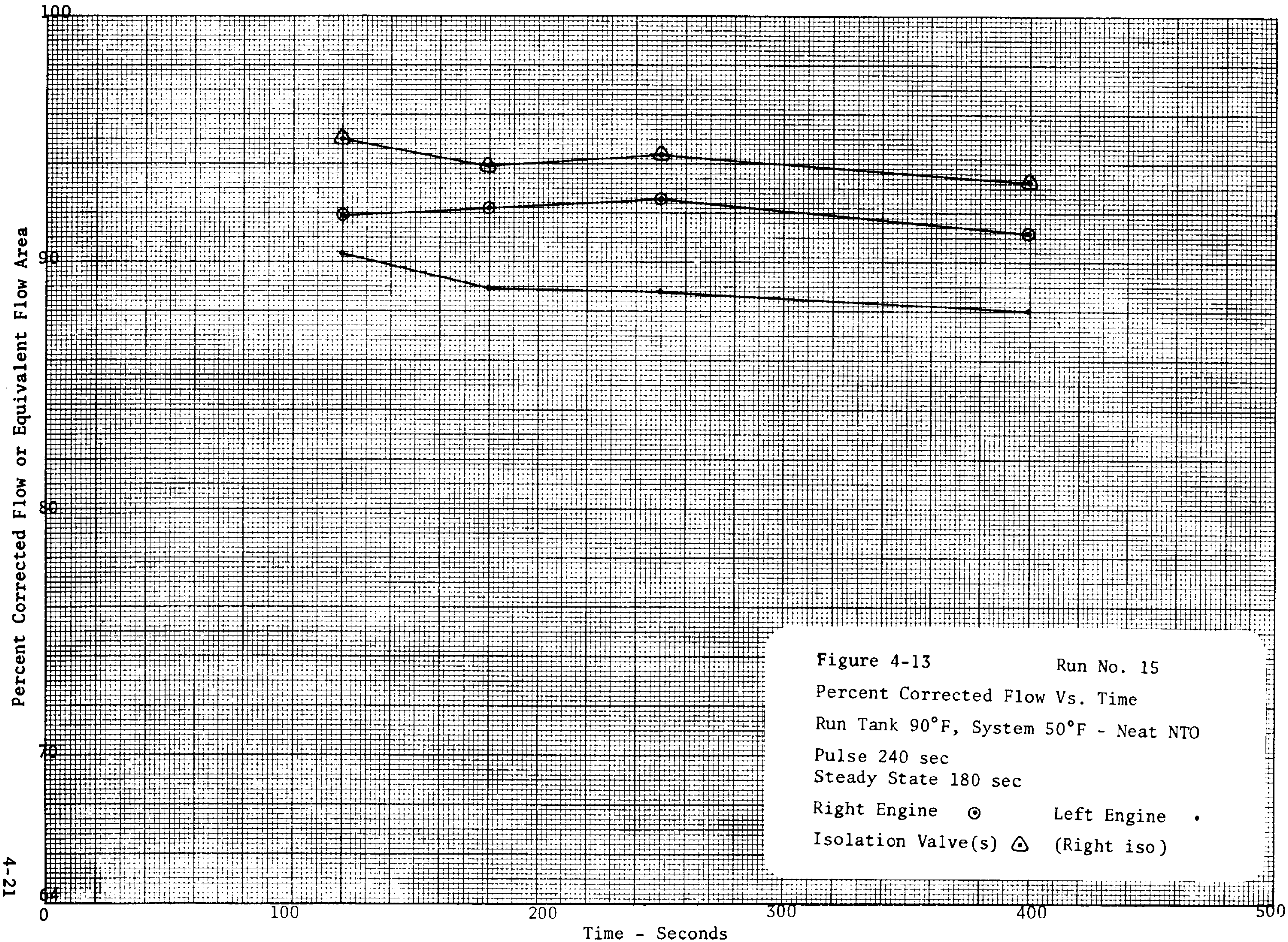


Figure 4-12 Run No. 14

Percent Corrected Flow Vs. Time

Run Tank 90°F, System 50°F - Neat NTO

Steady State 300 sec
Pulse 300 sec


100
90
80
70
64
Percent Corrected Flow or Equivalent Flow Area
0
100
200
300
400
500
Time - Seconds
Figure 4-13
Run No. 15
Percent Corrected Flow Vs. Time
Run Tank 90°F, System 50°F - Neat NTO
Pulse 240 sec
Steady State 180 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) △
(Right iso)

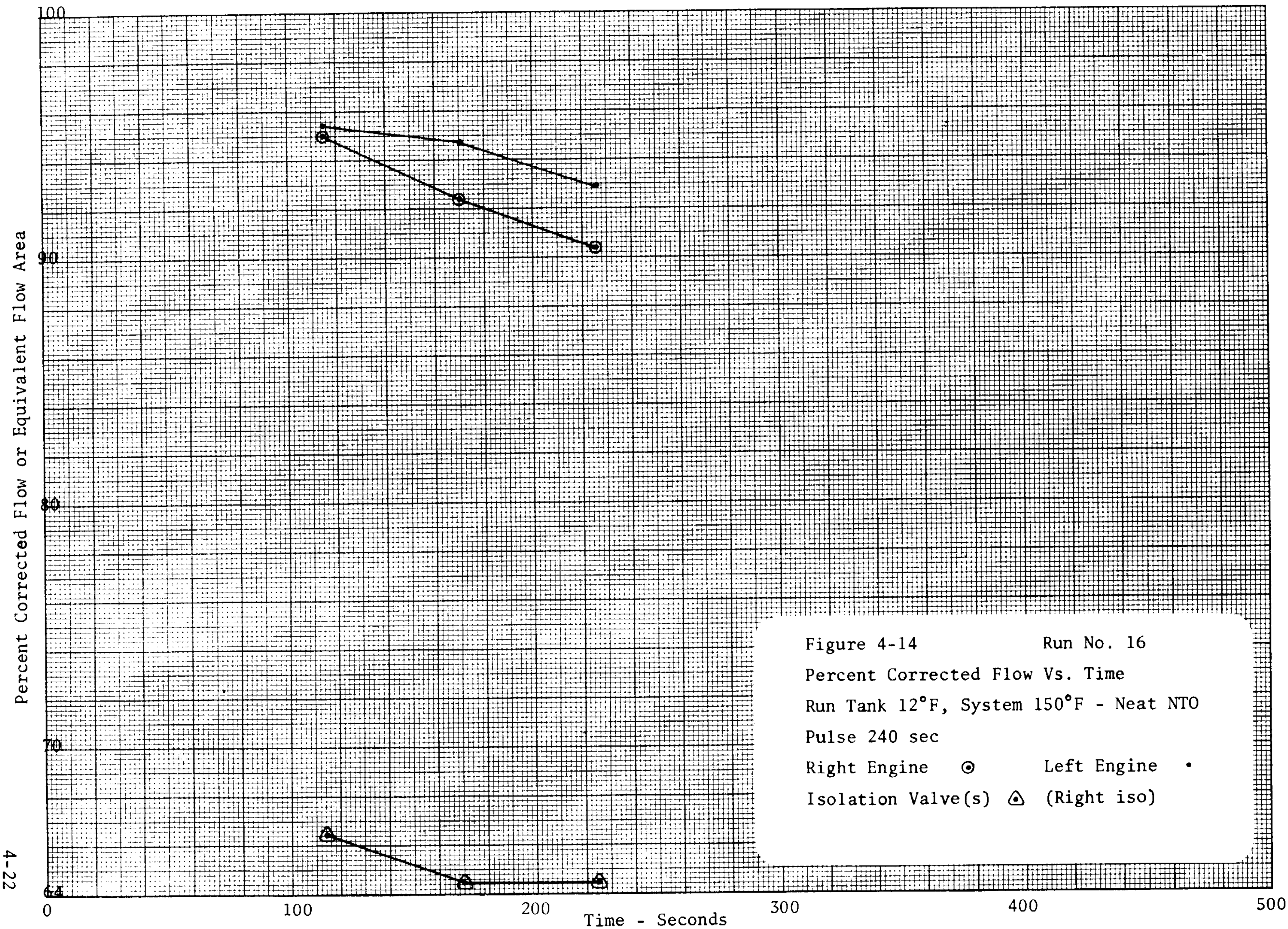


Figure 4-14 Run No. 16

Percent Corrected Flow Vs. Time

Run Tank 12°F, System 150°F - Neat NTO

Pulse 240 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Right iso)

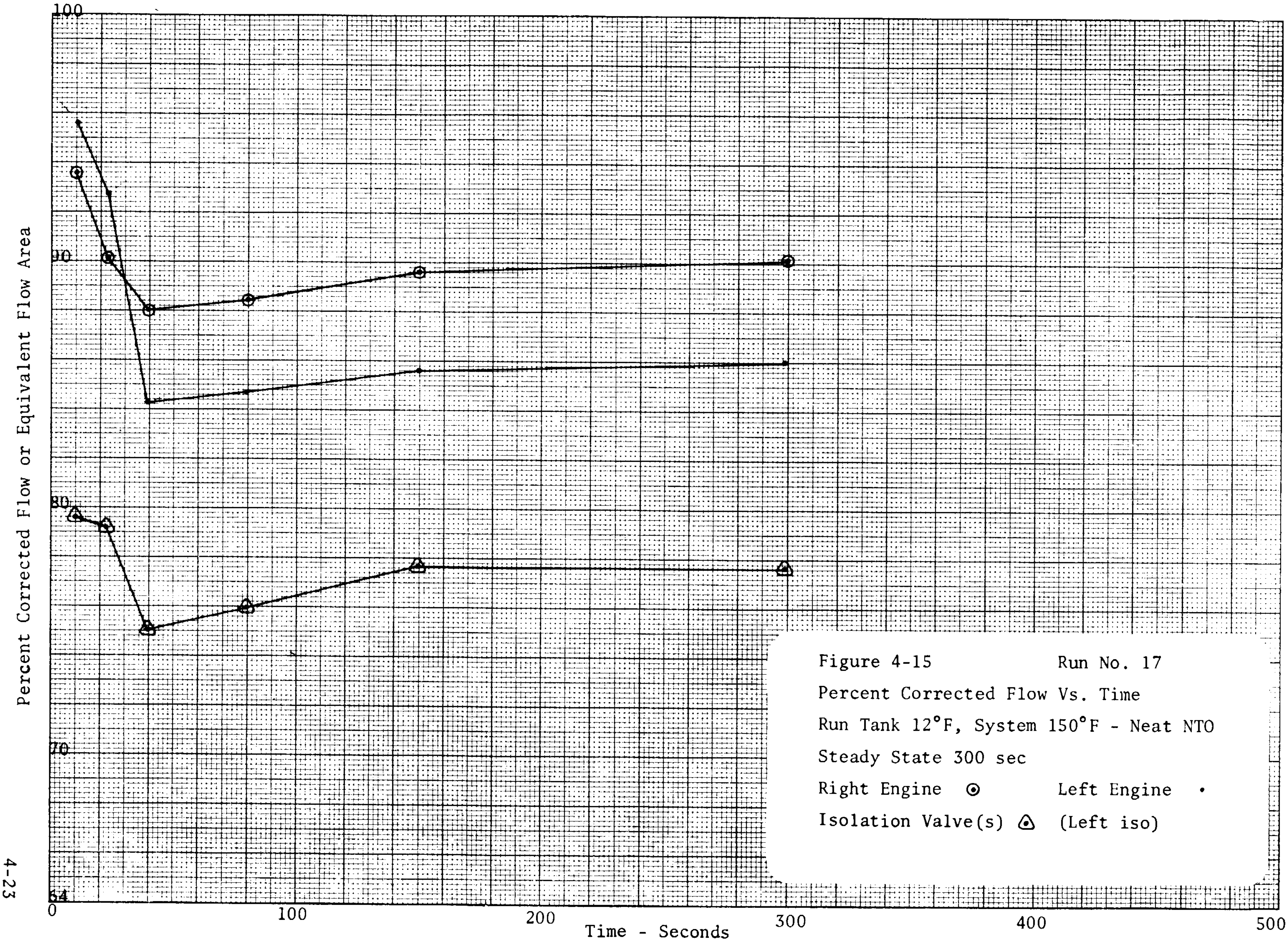


Figure 4-15 Run No. 17

Percent Corrected Flow Vs. Time

Run Tank 12°F, System 150°F - Neat NTO

Steady State 300 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Left iso)

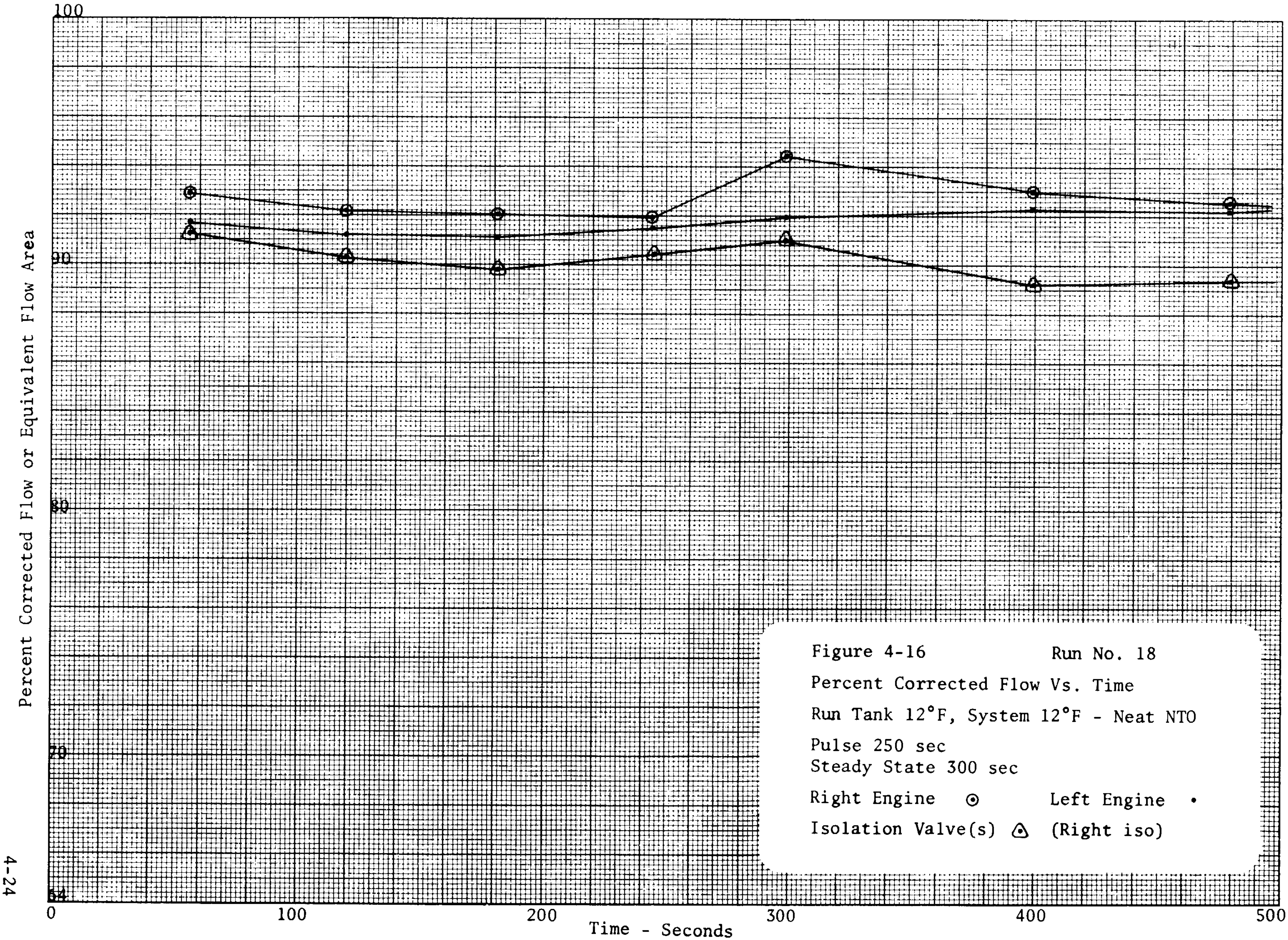


Figure 4-16 Run No. 18

Percent Corrected Flow Vs. Time

Run Tank 12°F, System 12°F - Neat NTO

Pulse 250 sec

Steady State 300 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Right iso)

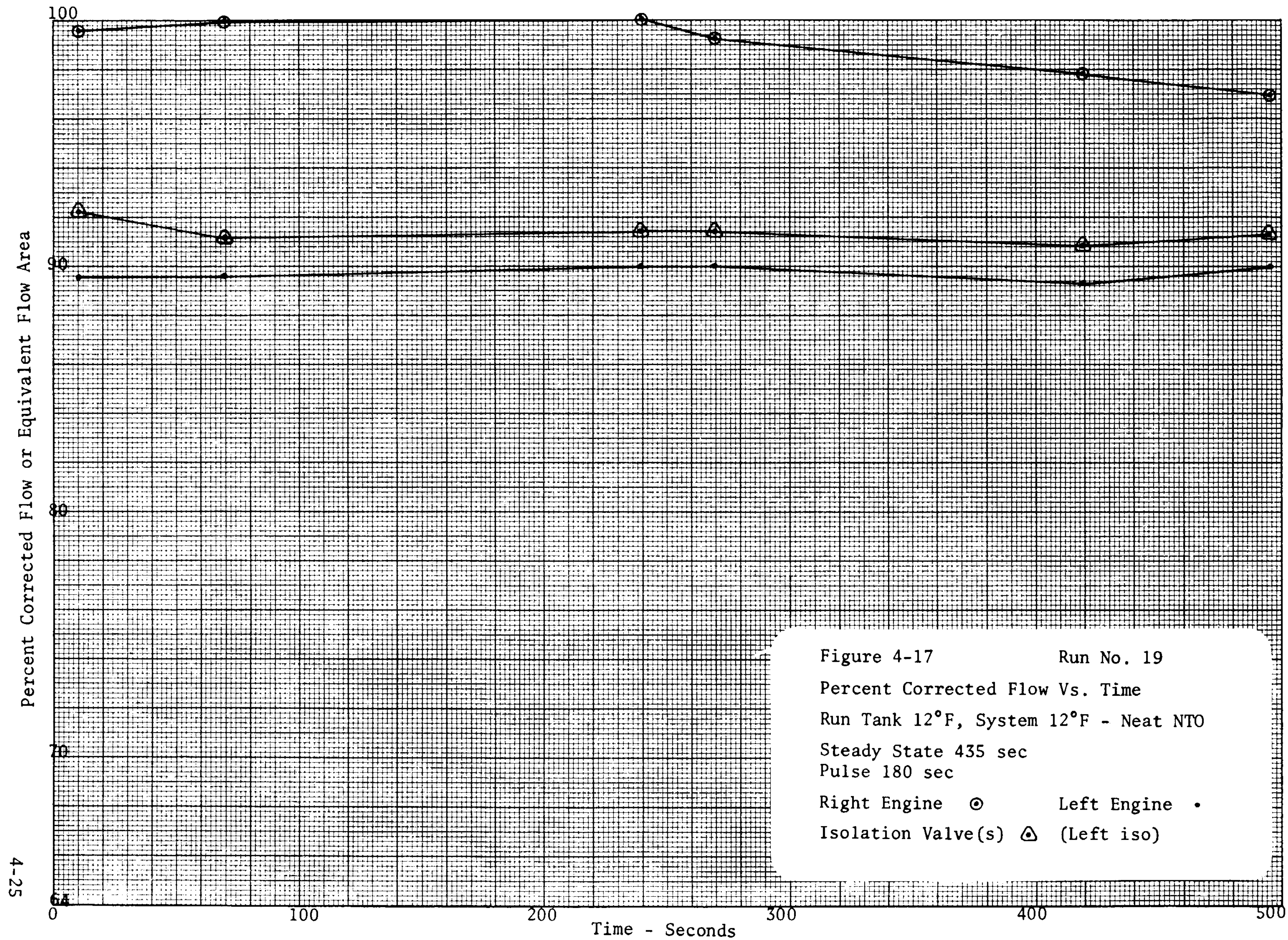


Figure 4-17 Run No. 19

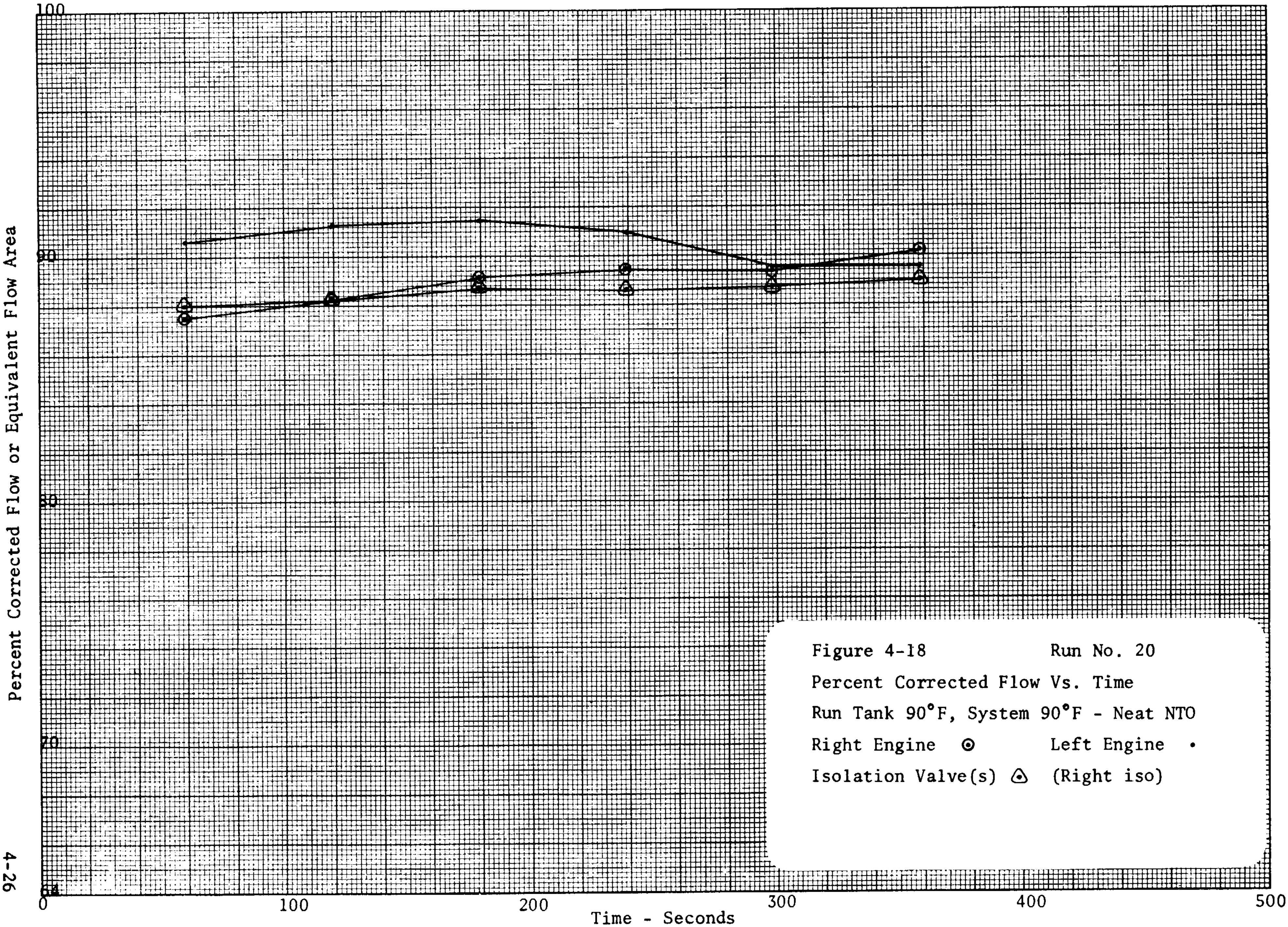
Percent Corrected Flow Vs. Time

Run Tank 12°F, System 12°F - Neat NTO

Steady State 435 sec
Pulse 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Left iso)



100
90
80
70
60
0
100
200
300
400
500
Time - Seconds
Percent Corrected Flow or Equivalent Flow Area
Figure 4-18 Run No. 20
Percent Corrected Flow Vs. Time
Run Tank 90°F, System 90°F - Neat NTO
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Right iso)

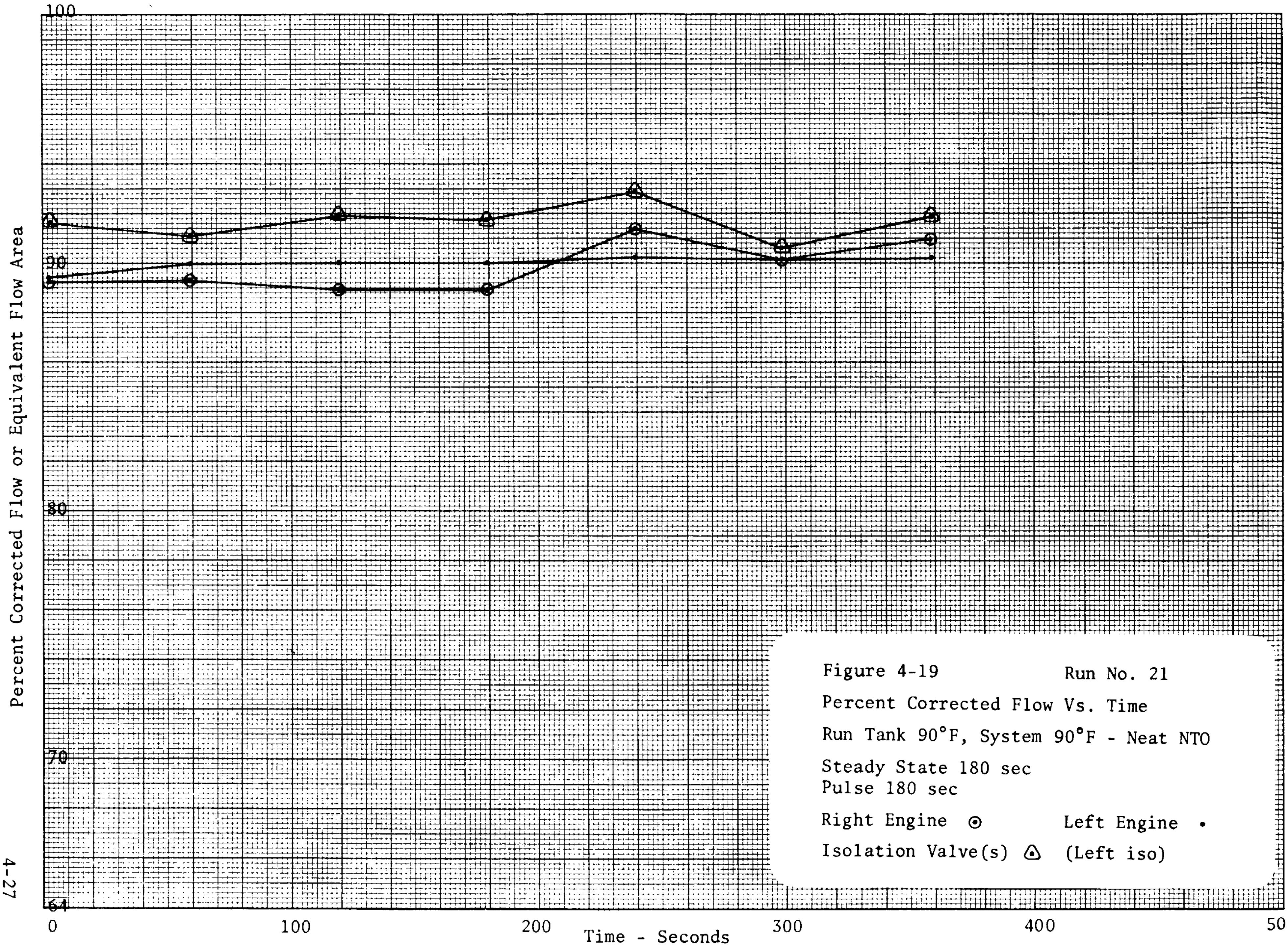
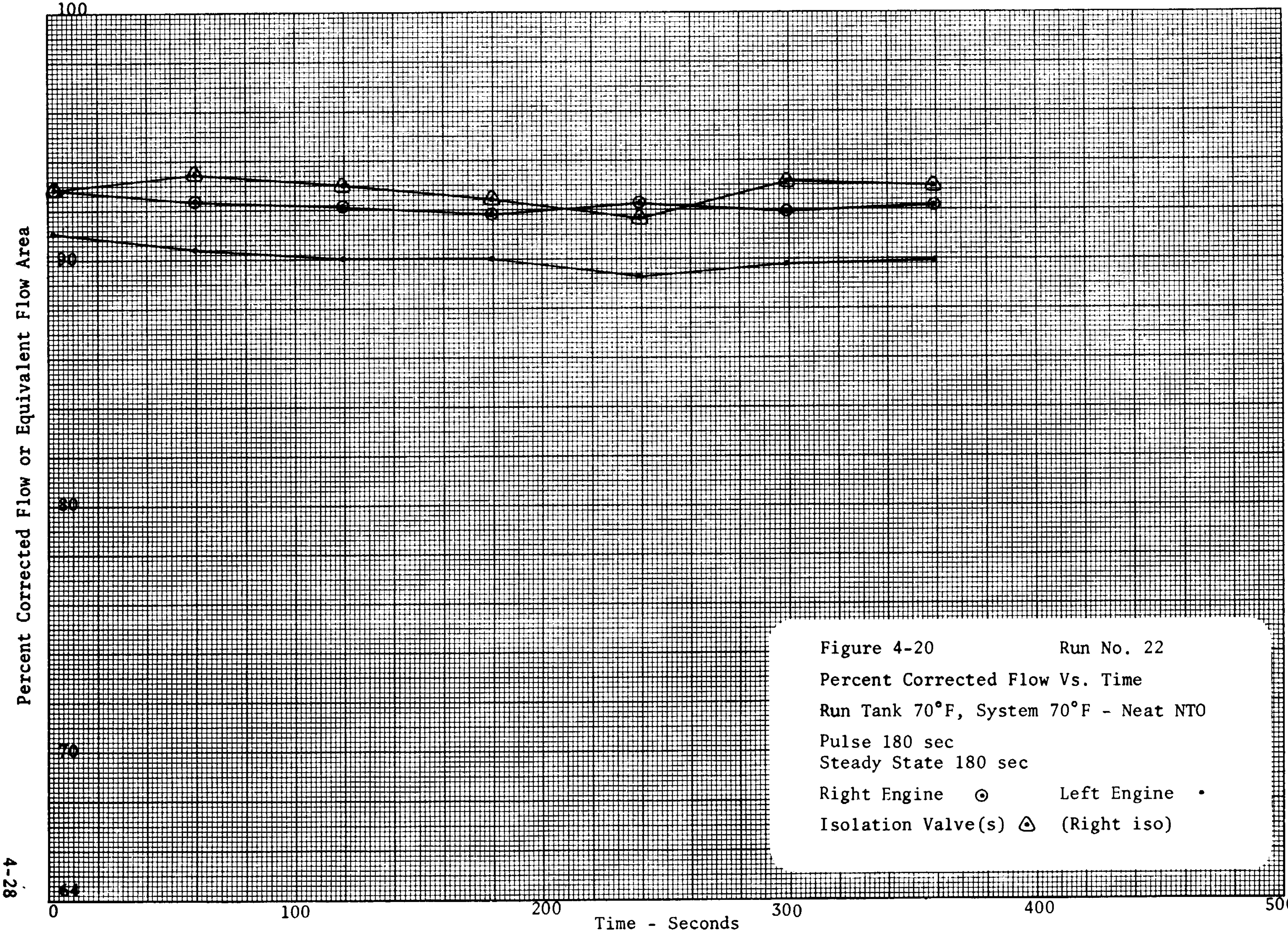


Figure 4-19
Run No. 21
Percent Corrected Flow Vs. Time
Run Tank 90°F, System 90°F - Neat NTO
Steady State 180 sec
Pulse 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)
Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
100
90
80
70
64
0
100
200
300
400
500


100
90
80
70
64
0
100
200
300
400
500
Time - Seconds
Percent Corrected Flow or Equivalent Flow Area
Figure 4-20
Run No. 22
Percent Corrected Flow Vs. Time
Run Tank 70°F, System 70°F - Neat NTO
Pulse 180 sec
Steady State 180 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) △
(Right iso)

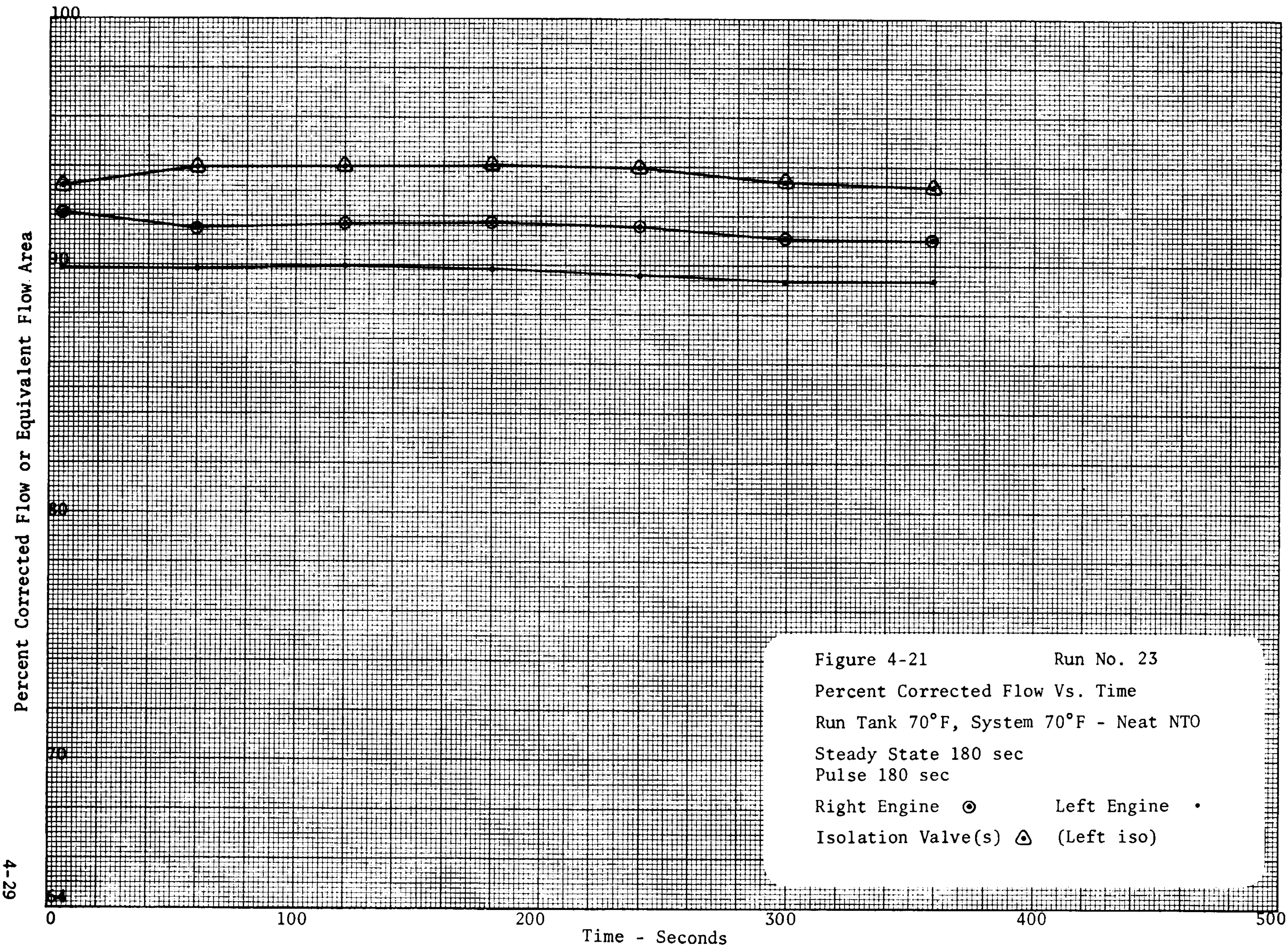


Figure 4-21 Run No. 23

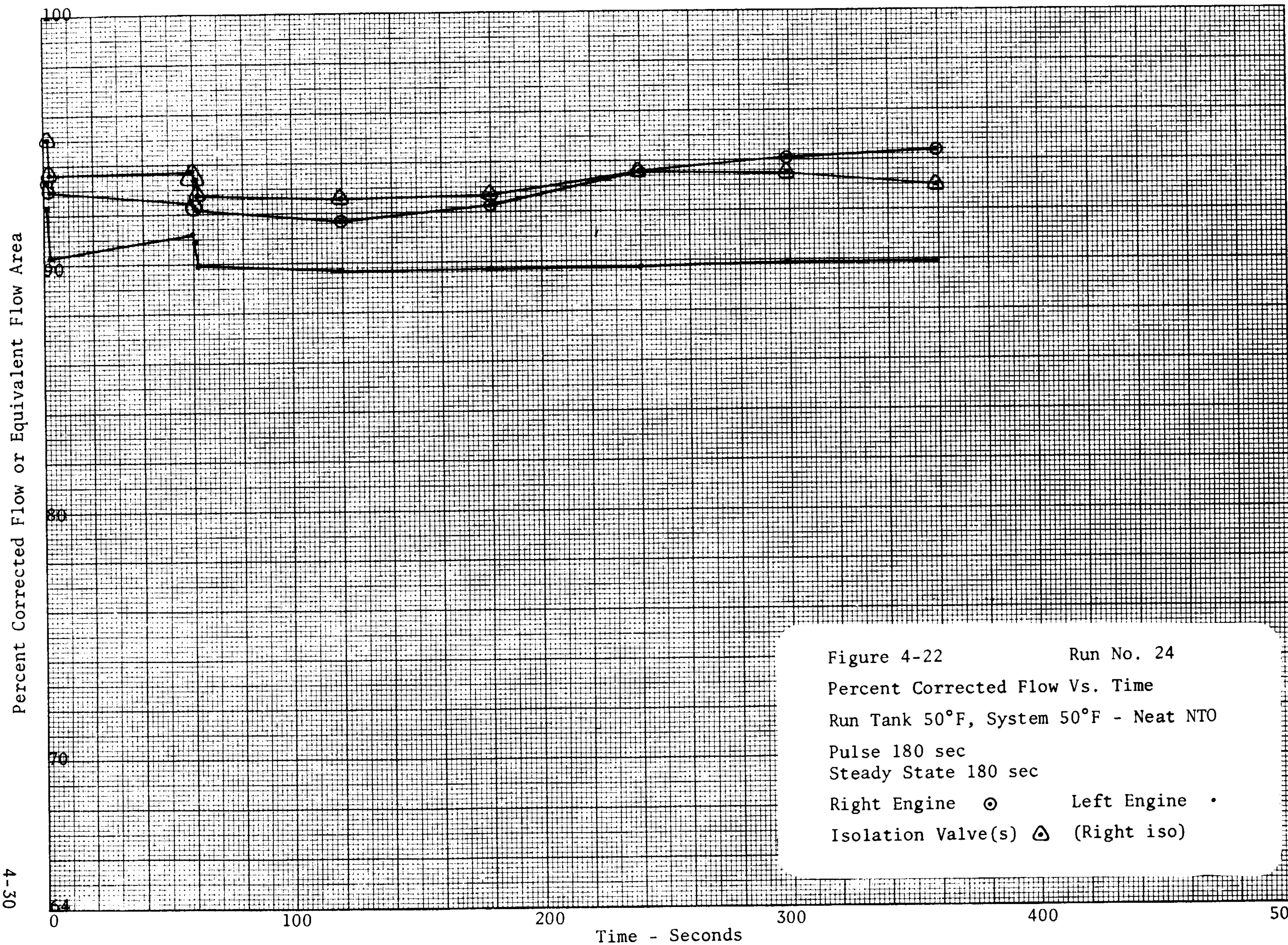
Percent Corrected Flow Vs. Time

Run Tank 70°F, System 70°F - Neat NTO

Steady State 180 sec
Pulse 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Left iso)


100
90
80
70
64
0
100
200
300
400
500
Time - Seconds
Percent Corrected Flow or Equivalent Flow Area
Figure 4-22
Run No. 24
Percent Corrected Flow Vs. Time
Run Tank 50°F, System 50°F - Neat NTO
Pulse 180 sec
Steady State 180 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) △
(Right iso)

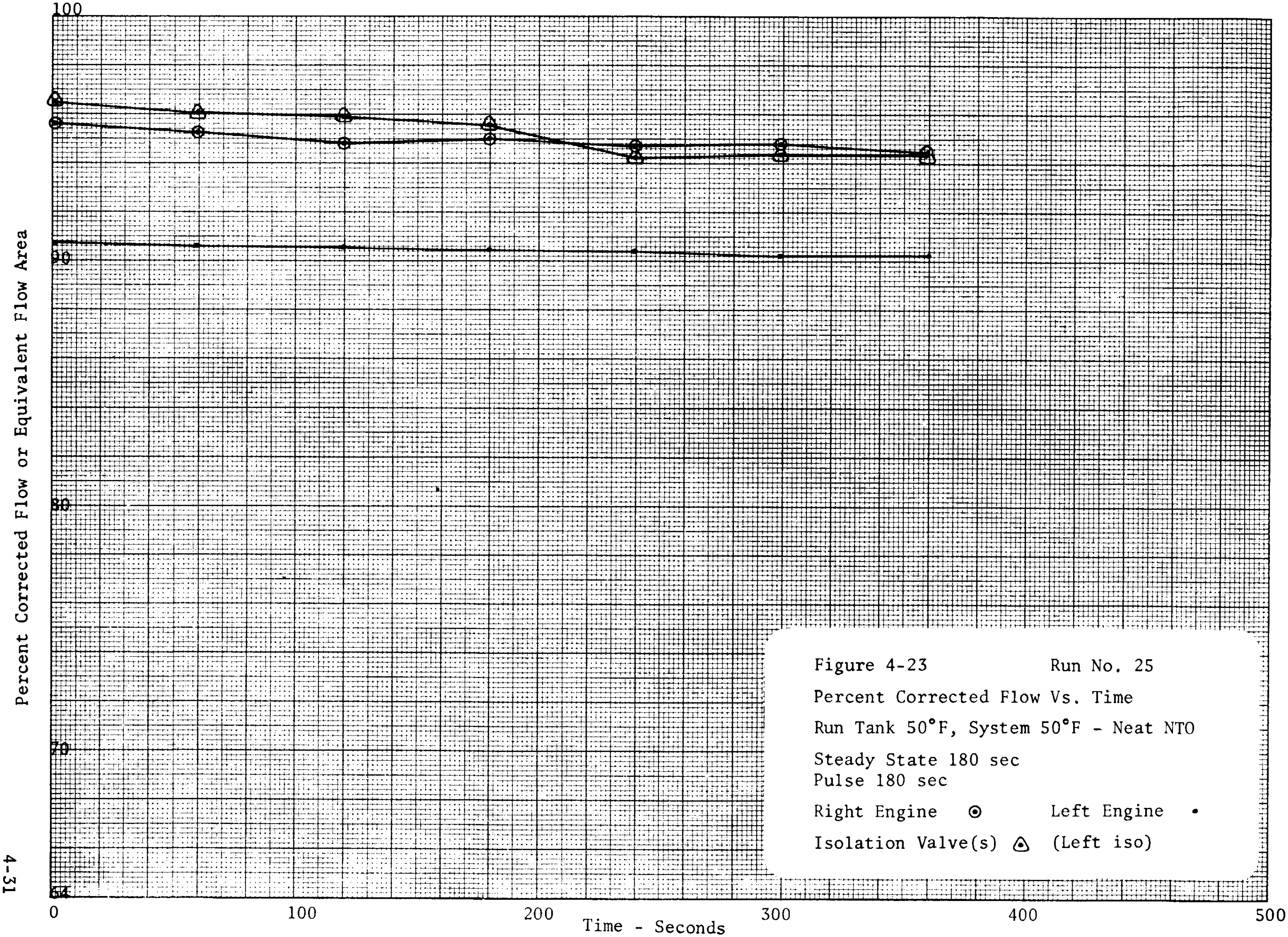


Figure 4-23 Run No. 25
Percent Corrected Flow Vs. Time
Run Tank 50°F, System 50°F - Neat NTO
Steady State 180 sec
Pulse 180 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Left iso)
Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
100
90
80
70
64
0
100
200
300
400
500

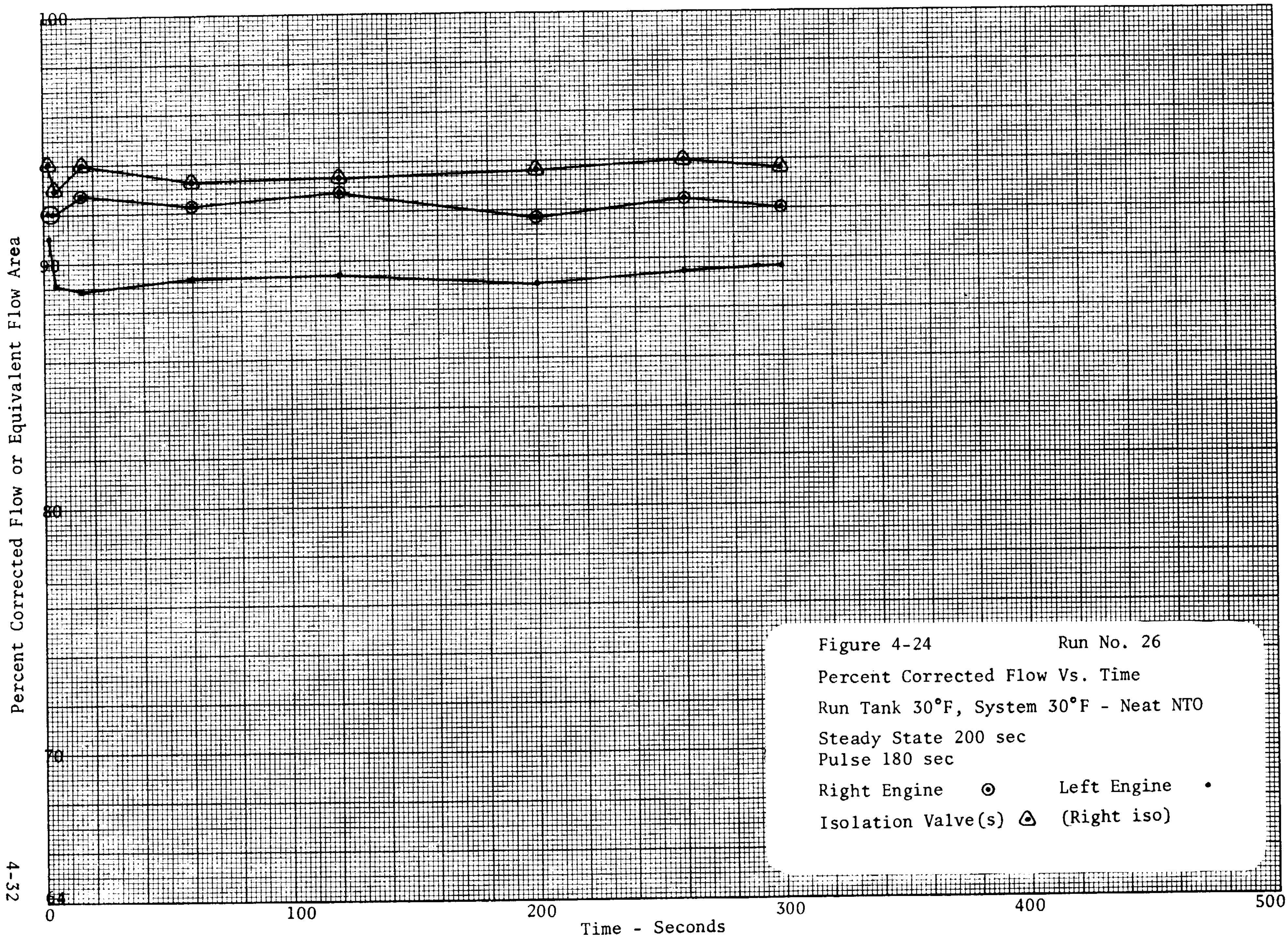


Figure 4-24

Percent Corrected Flow Vs. Time

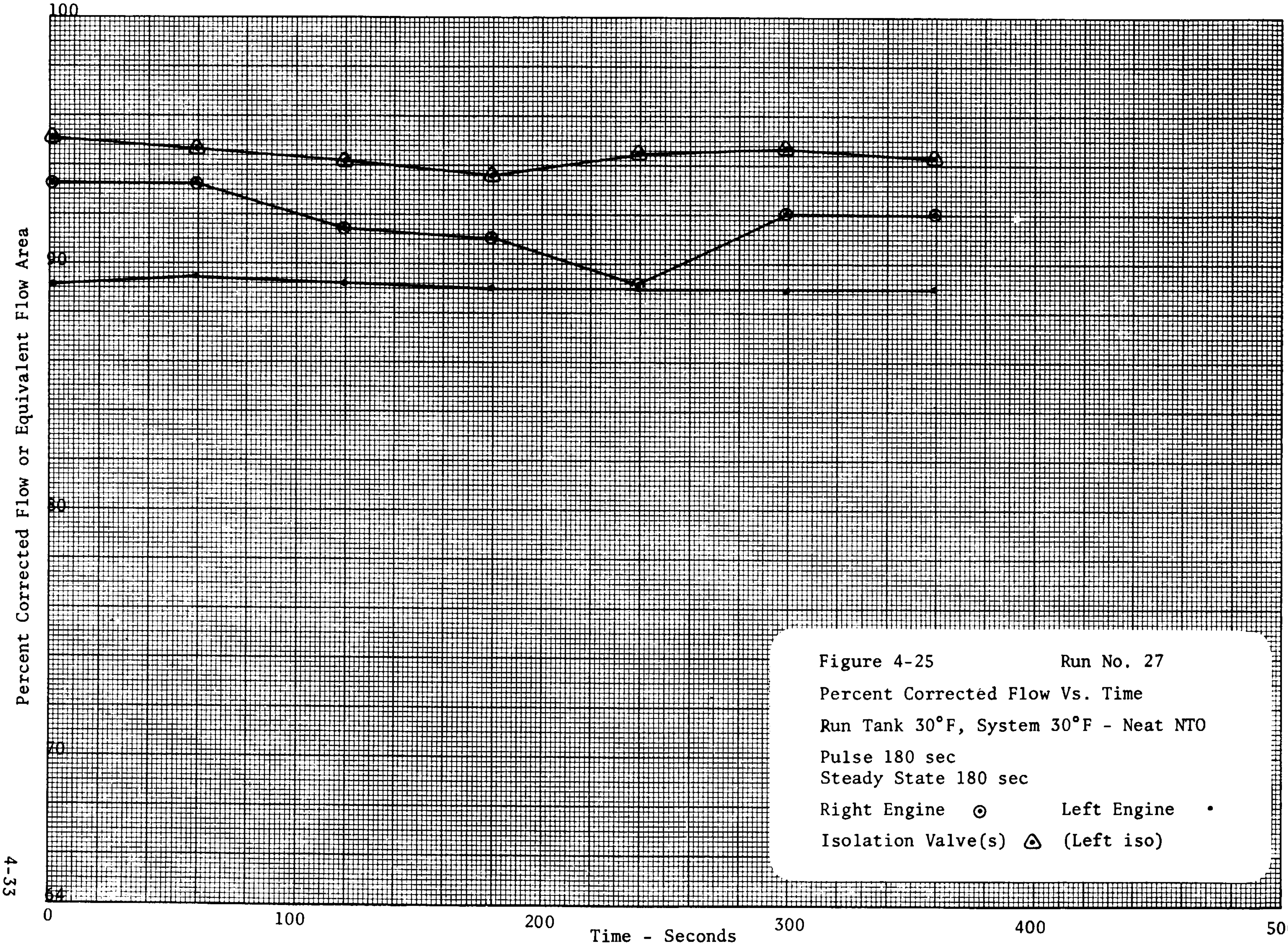


Figure 4-25
Run No. 27
Percent Corrected Flow Vs. Time
Run Tank 30°F, System 30°F - Neat NTO
Pulse 180 sec
Steady State 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)
Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
100
90
80
70
64
0
100
200
300
400
500

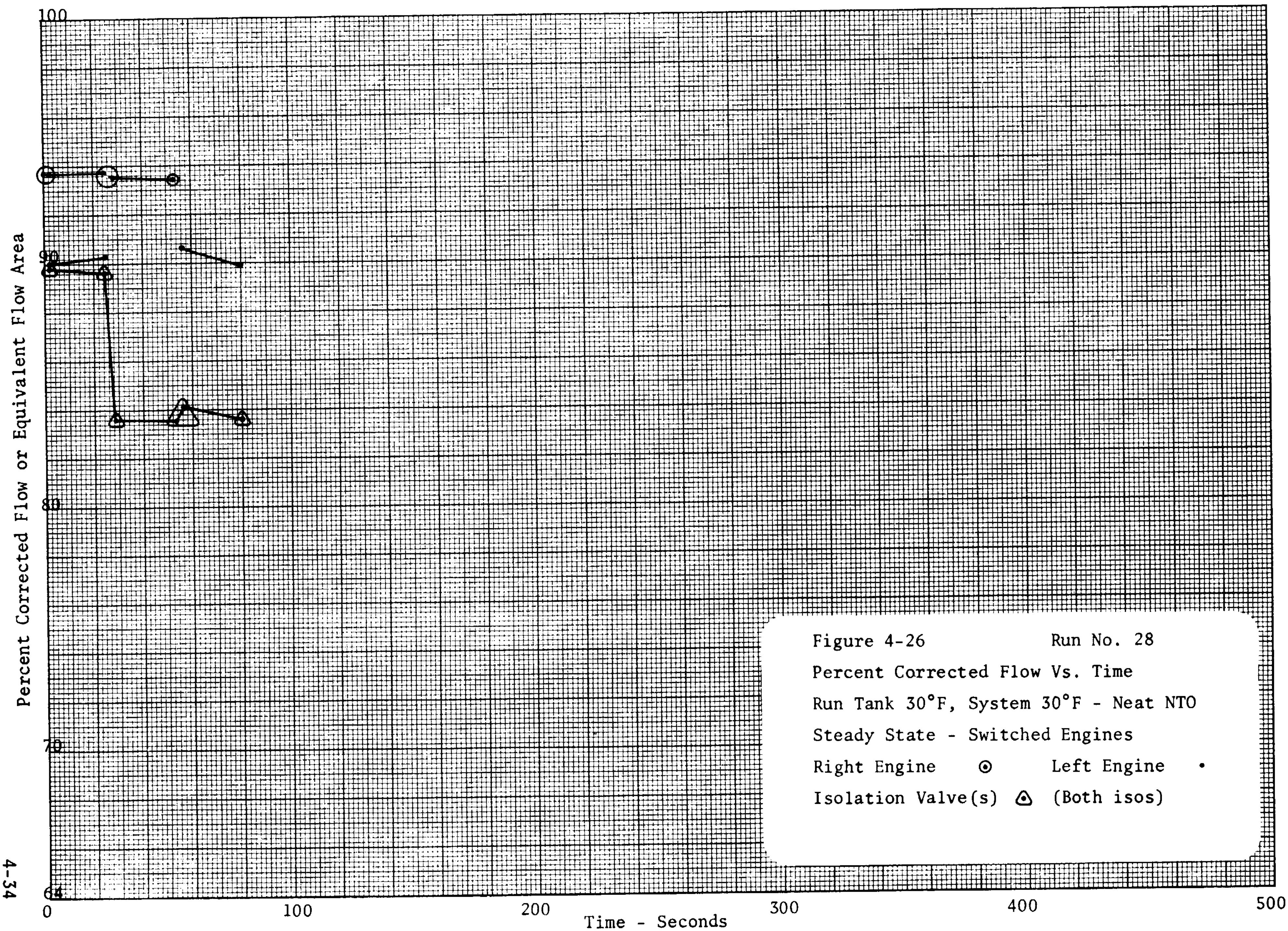


Figure 4-26 Run No. 28

Percent Corrected Flow Vs. Time

Run Tank 30°F, System 30°F - Neat NTO

Steady State - Switched Engines

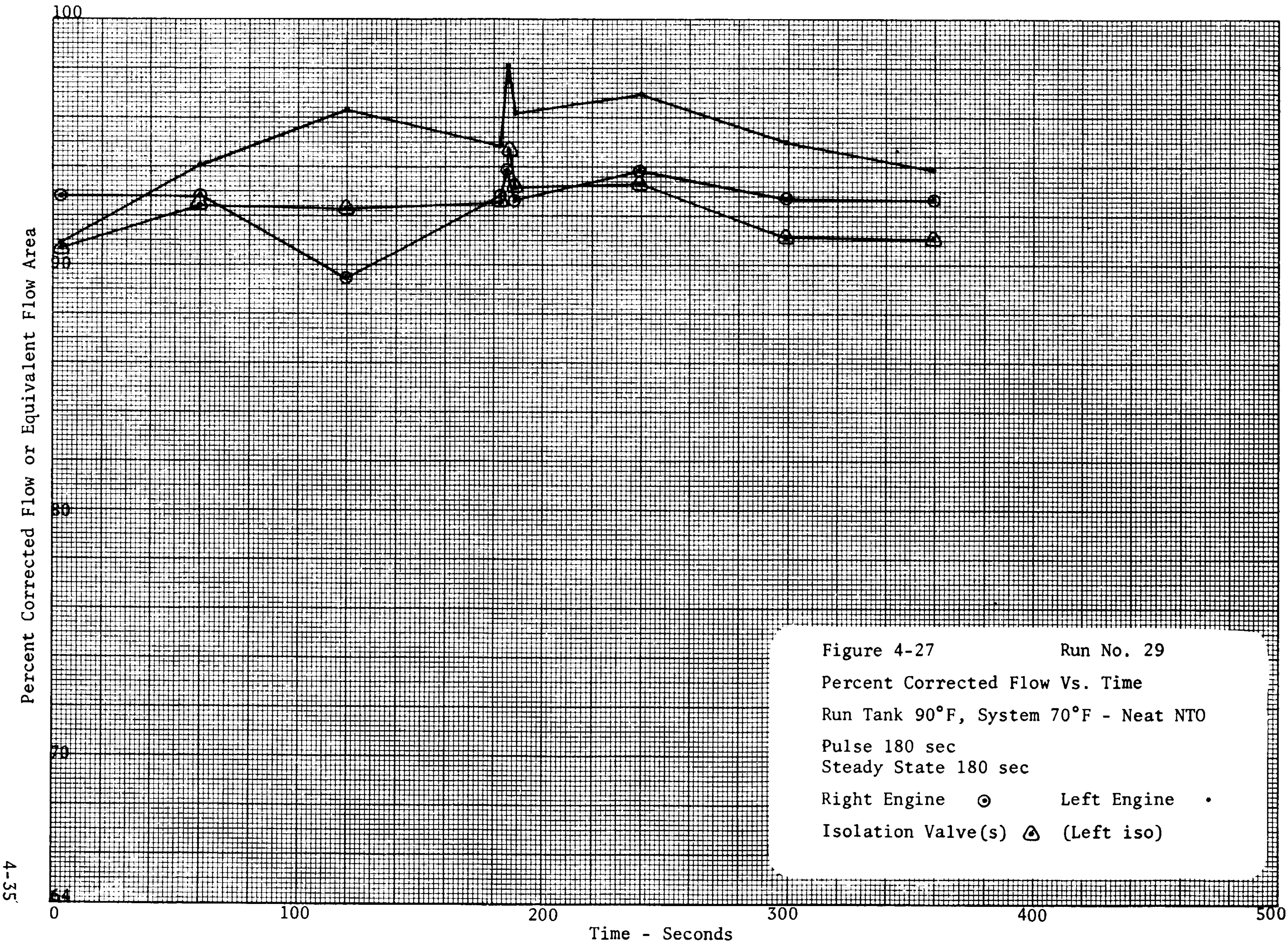


Figure 4-27 Run No. 29

Percent Corrected Flow Vs. Time

Run Tank 90°F, System 70°F - Neat NTO

Pulse 180 sec
Steady State 180 sec

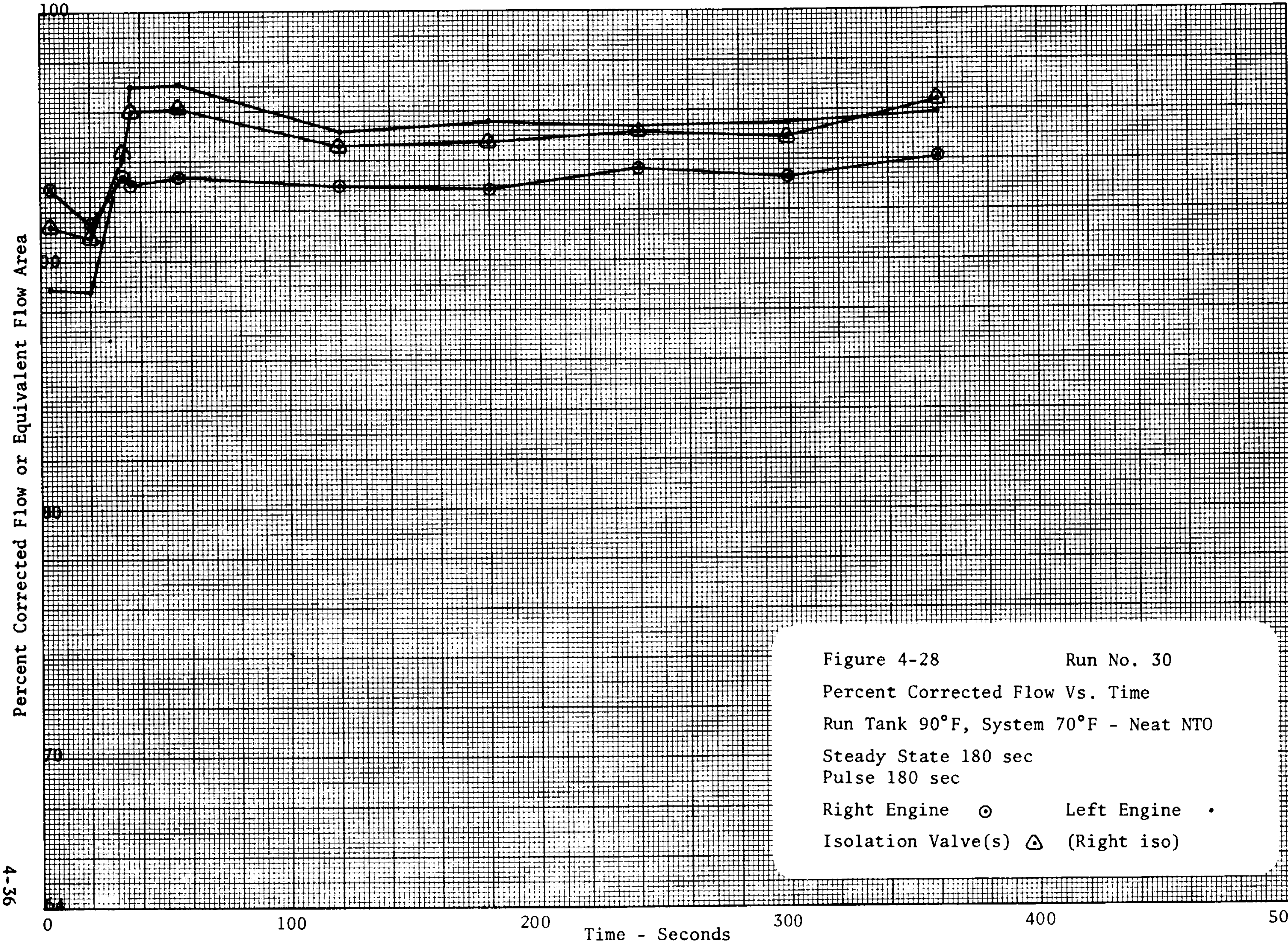


Figure 4-28 Run No. 30

Percent Corrected Flow Vs. Time

Run Tank 90°F, System 70°F - Neat NTO

Steady State 180 sec
Pulse 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Right iso)

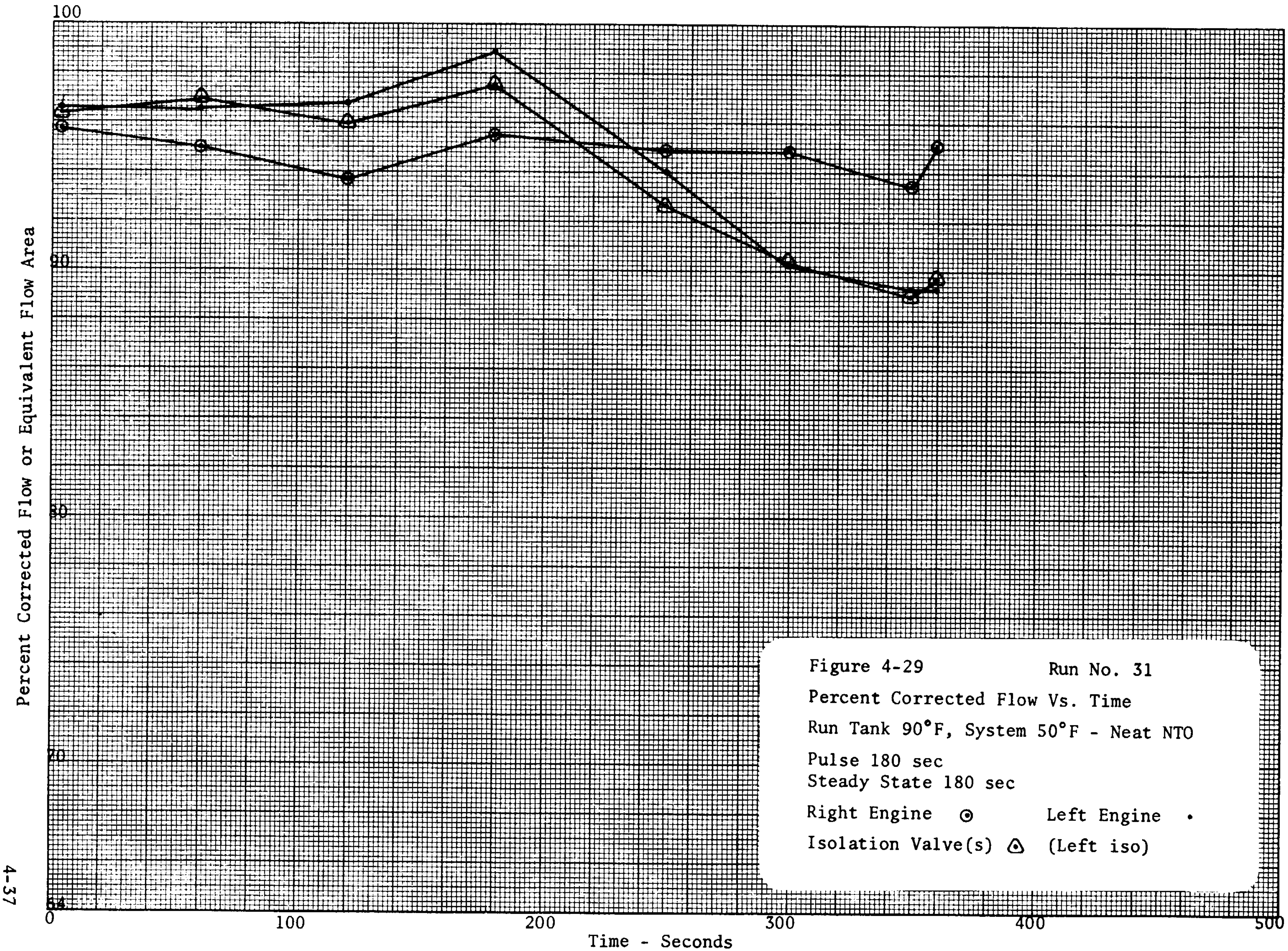


Figure 4-29 Run No. 31

Percent Corrected Flow Vs. Time

Run Tank 90°F, System 50°F - Neat NTO

Pulse 180 sec
Steady State 180 sec

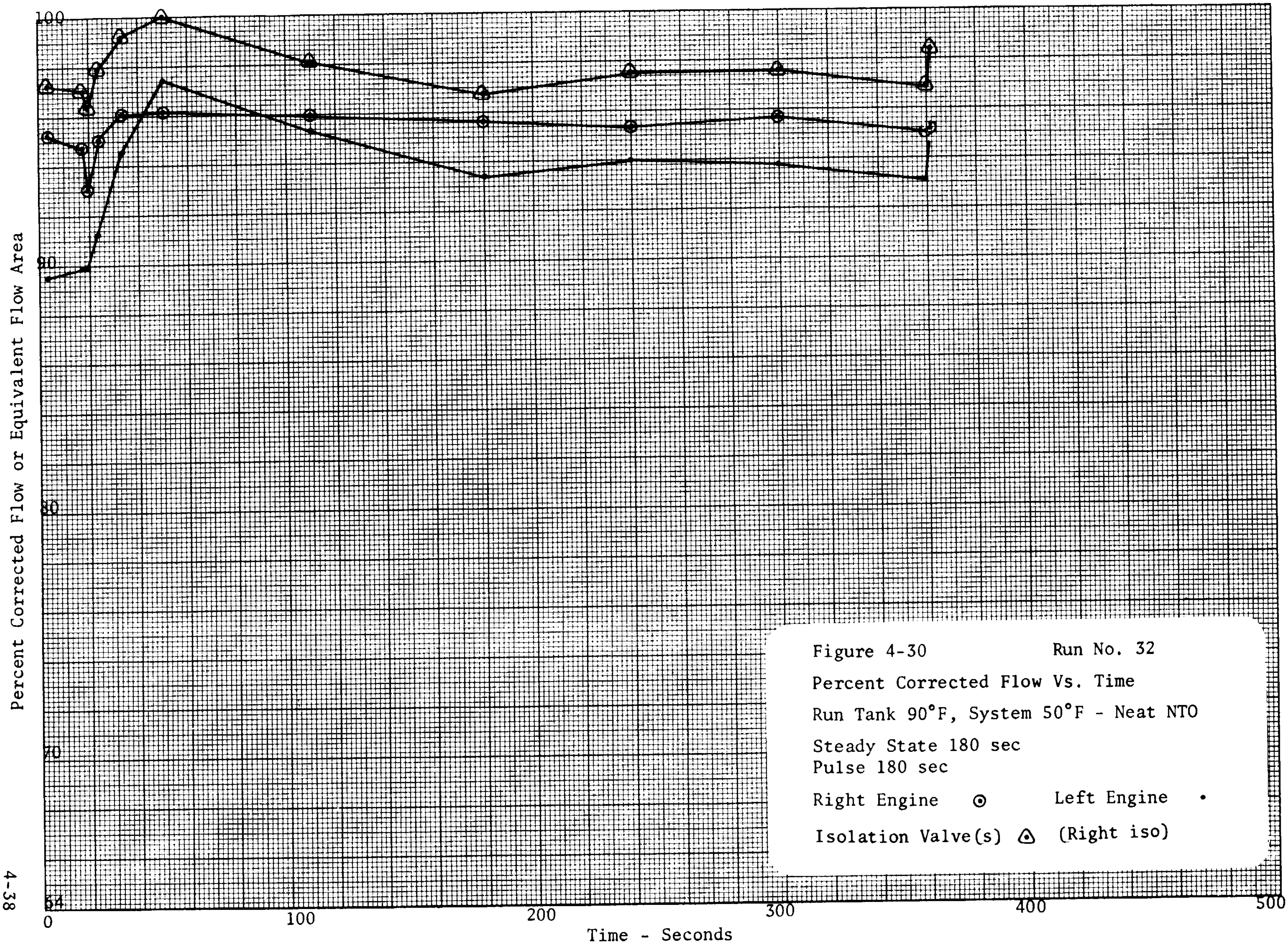
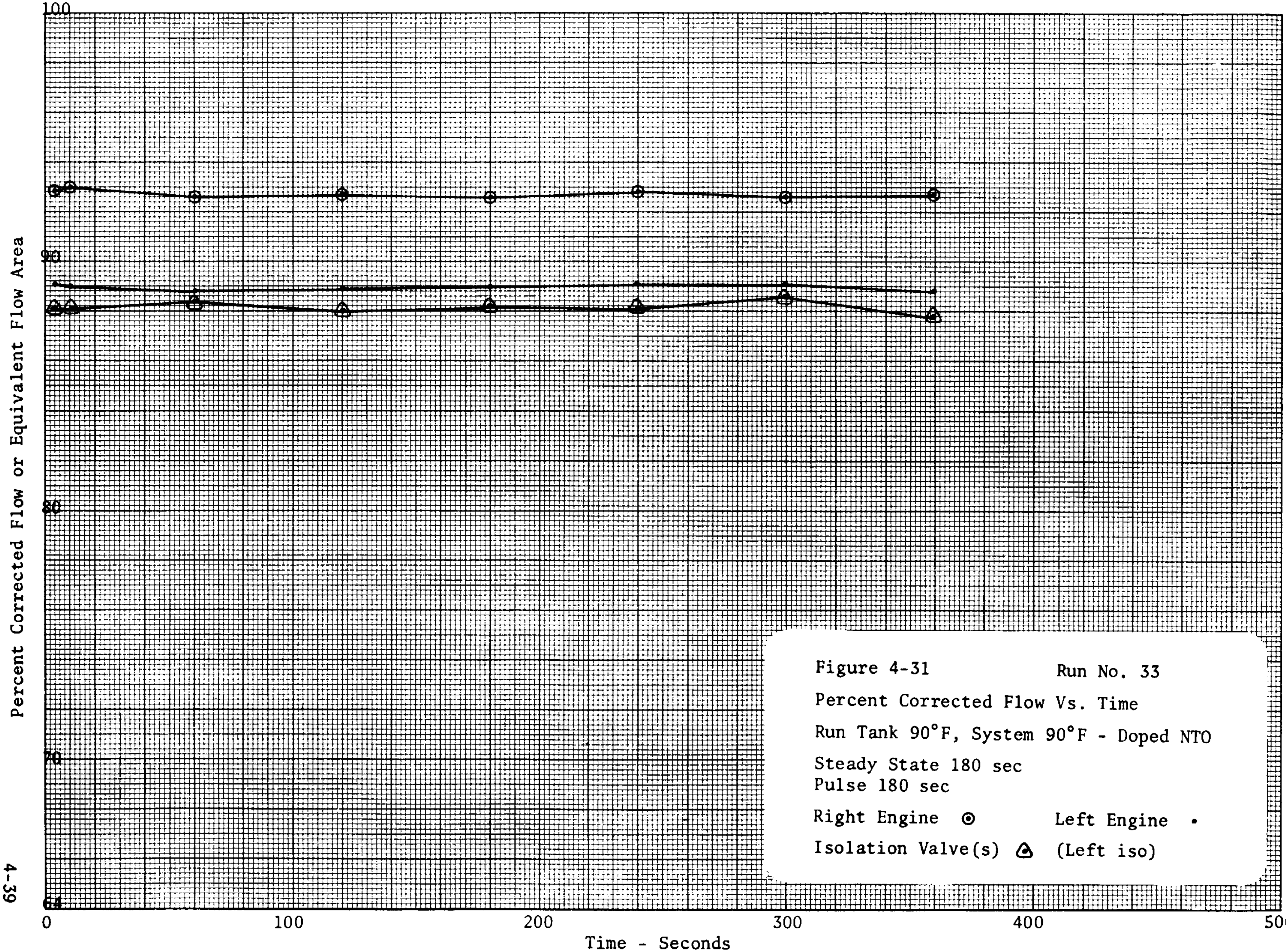
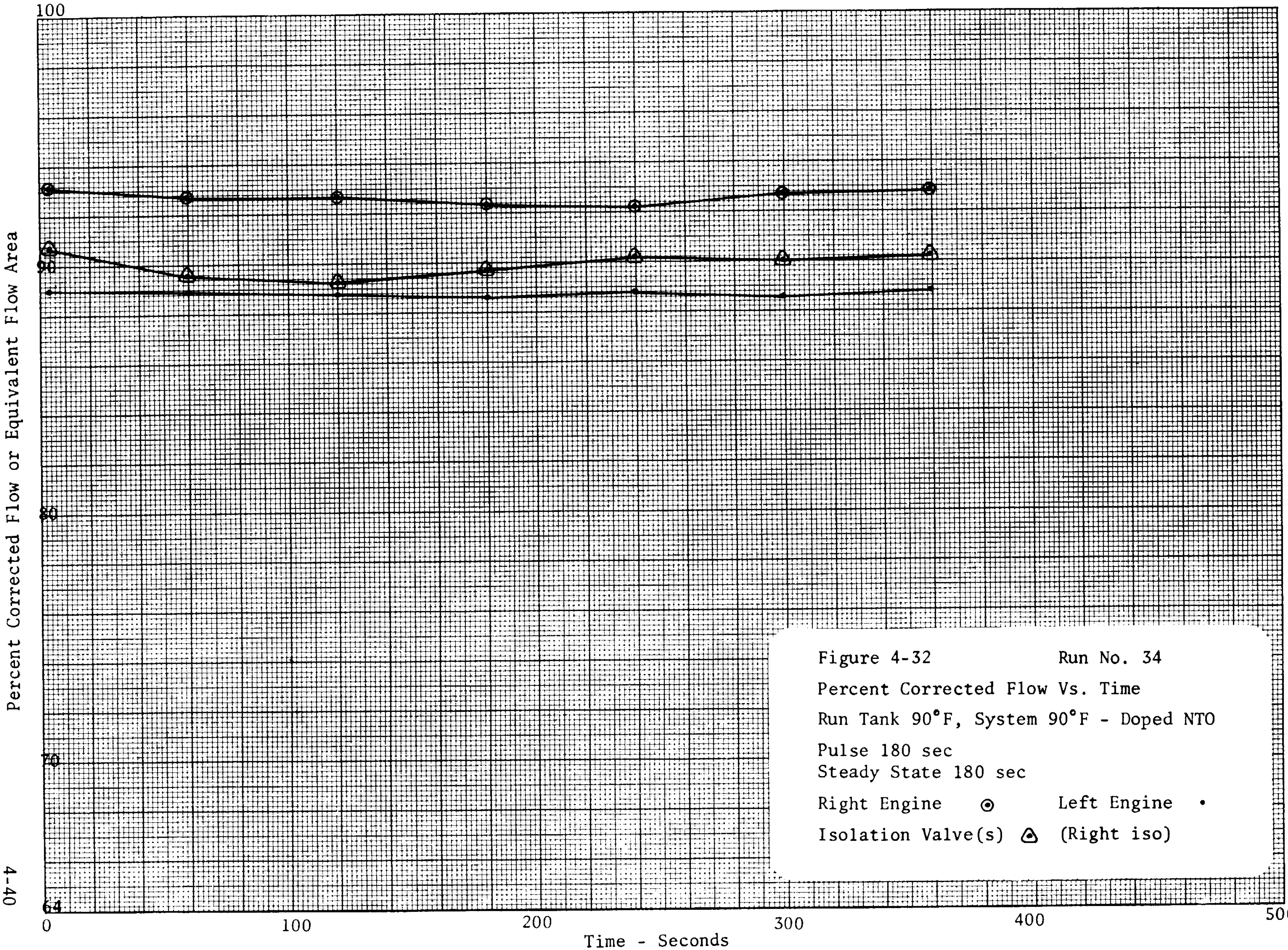


Figure 4-30
Run No. 32
Percent Corrected Flow Vs. Time
Run Tank 90°F, System 50°F - Neat NTO
Steady State 180 sec
Pulse 180 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) △ (Right iso)
Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
100
90
80
70
64
0
100
200
300
400
500



100
90
80
70
64
0
100
200
300
400
500
Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
Figure 4-31
Run No. 33
Percent Corrected Flow Vs. Time
Run Tank 90°F, System 90°F - Doped NTO
Steady State 180 sec
Pulse 180 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) △
(Left iso)



100
90
80
70
64
0
100
200
300
400
500
Time - Seconds
Percent Corrected Flow or Equivalent Flow Area
Figure 4-32
Run No. 34
Percent Corrected Flow Vs. Time
Run Tank 90°F, System 90°F - Doped NTO
Pulse 180 sec
Steady State 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)

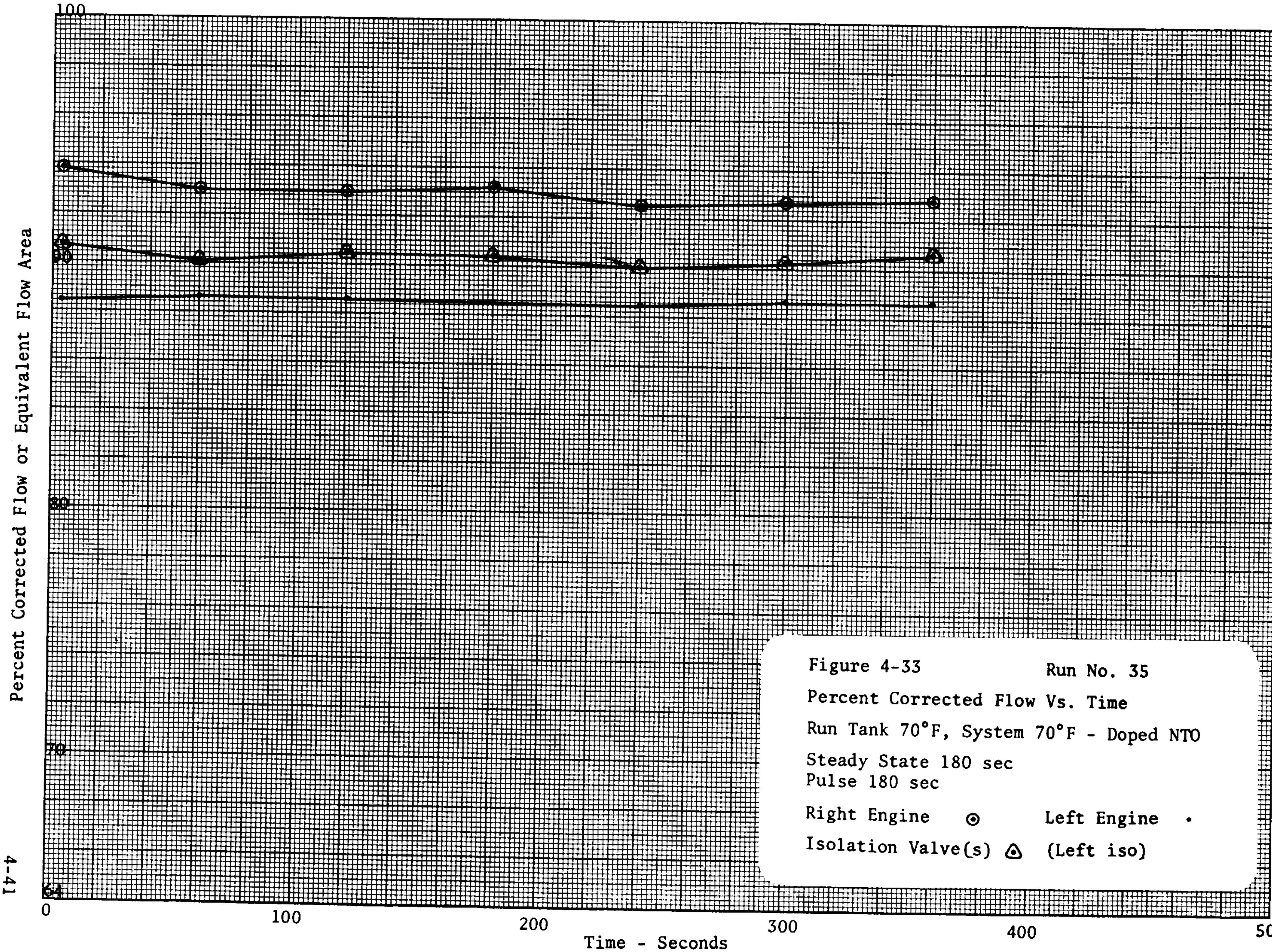


Figure 4-33 Run No. 35

Percent Corrected Flow Vs. Time

Run Tank 70°F, System 70°F - Doped NTO

Steady State 180 sec
Pulse 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Left iso)

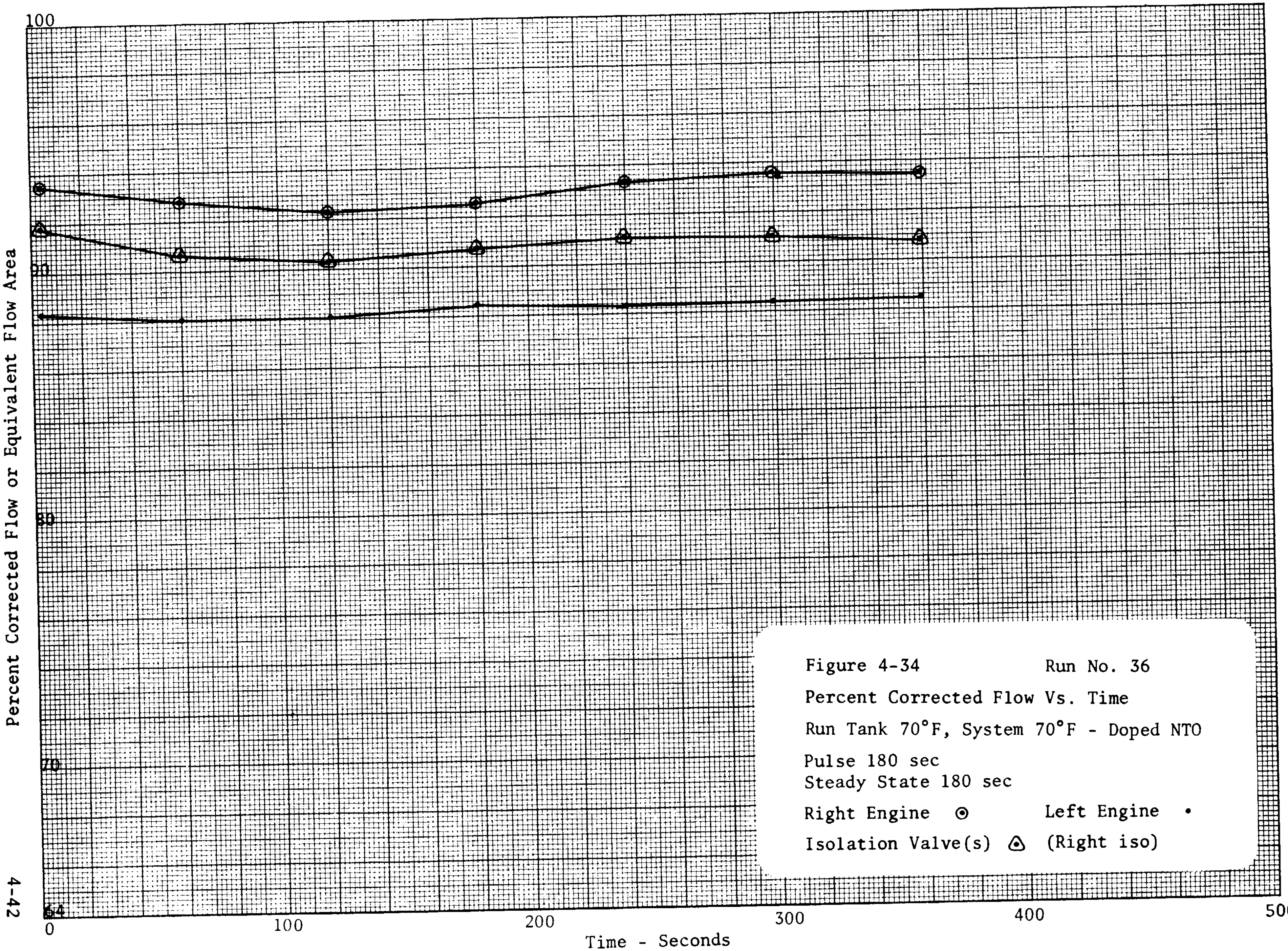
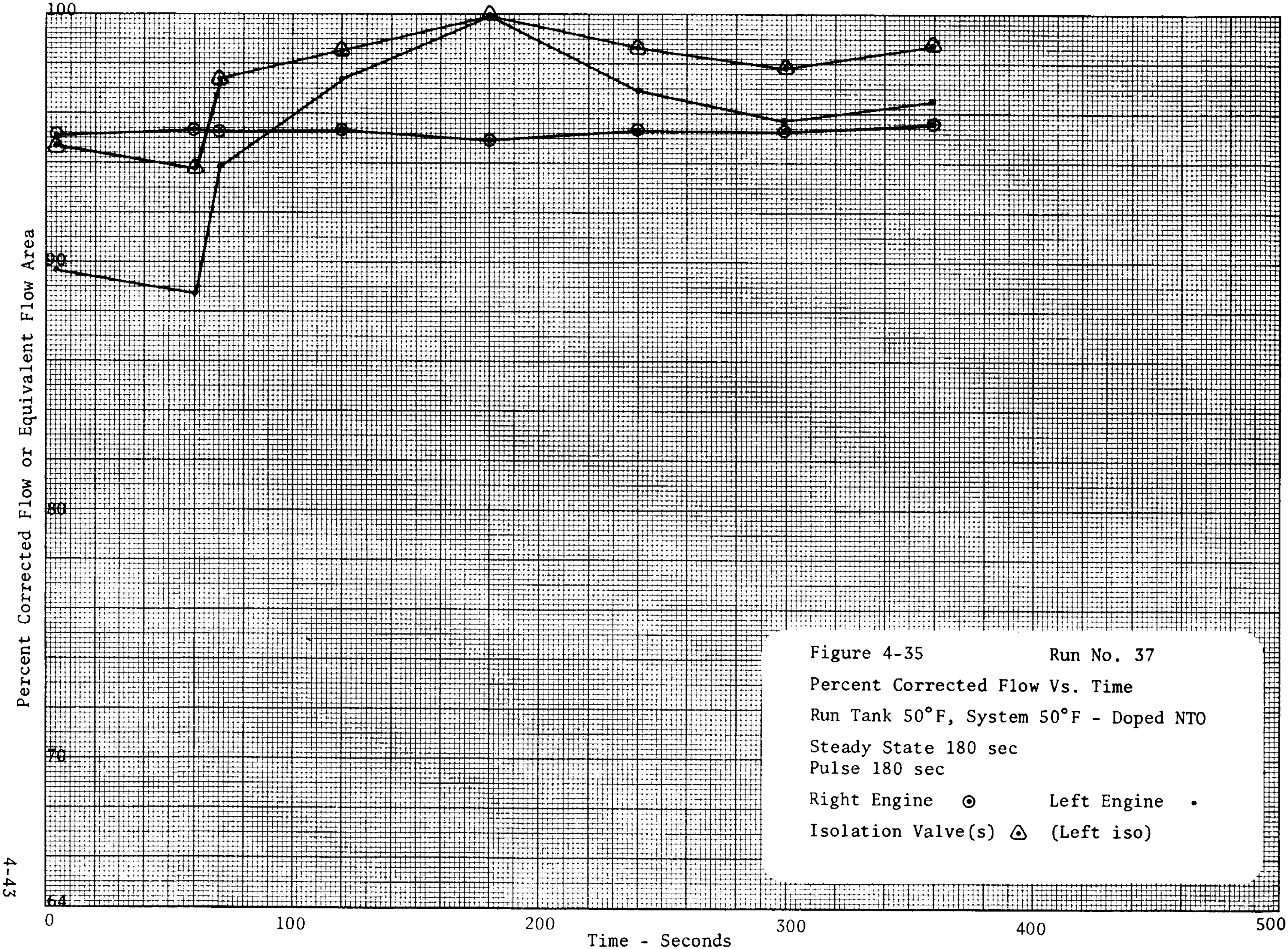


Figure 4-34 Run No. 36
Percent Corrected Flow Vs. Time
Run Tank 70°F, System 70°F - Doped NTO
Pulse 180 sec
Steady State 180 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) (Right iso)
Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
100
90
80
70
64
0
100
200
300
400
500


100
90
80
70
64
0
100
200
300
400
500
Percent Corrected Flow or Equivalent Flow Area
Time - Seconds
Figure 4-35
Run No. 37
Percent Corrected Flow Vs. Time
Run Tank 50°F, System 50°F - Doped NTO
Steady State 180 sec
Pulse 180 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) (Left iso)

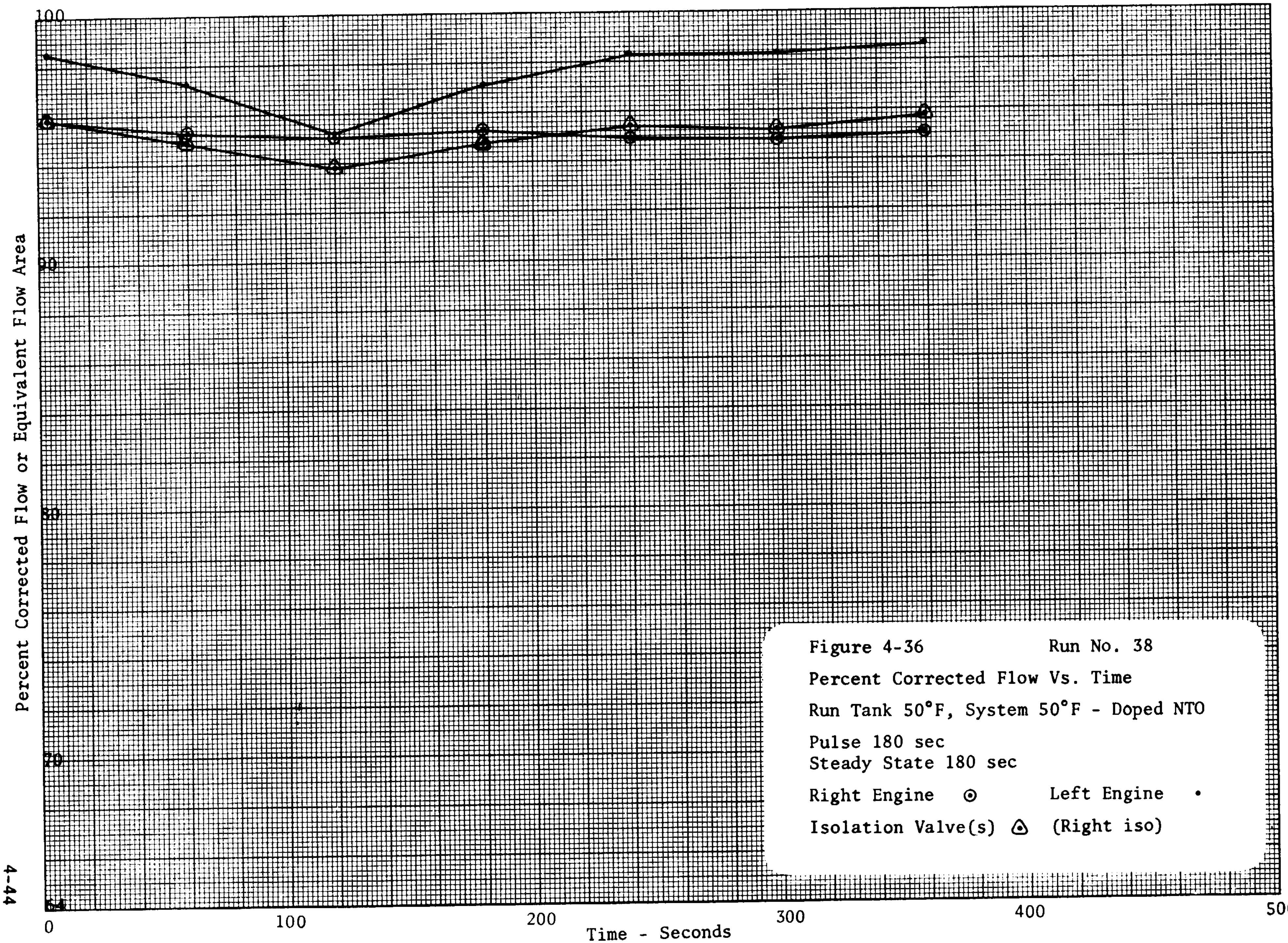


Figure 4-36 Run No. 38

Percent Corrected Flow Vs. Time

Run Tank 50°F, System 50°F - Doped NTO

Pulse 180 sec
Steady State 180 sec

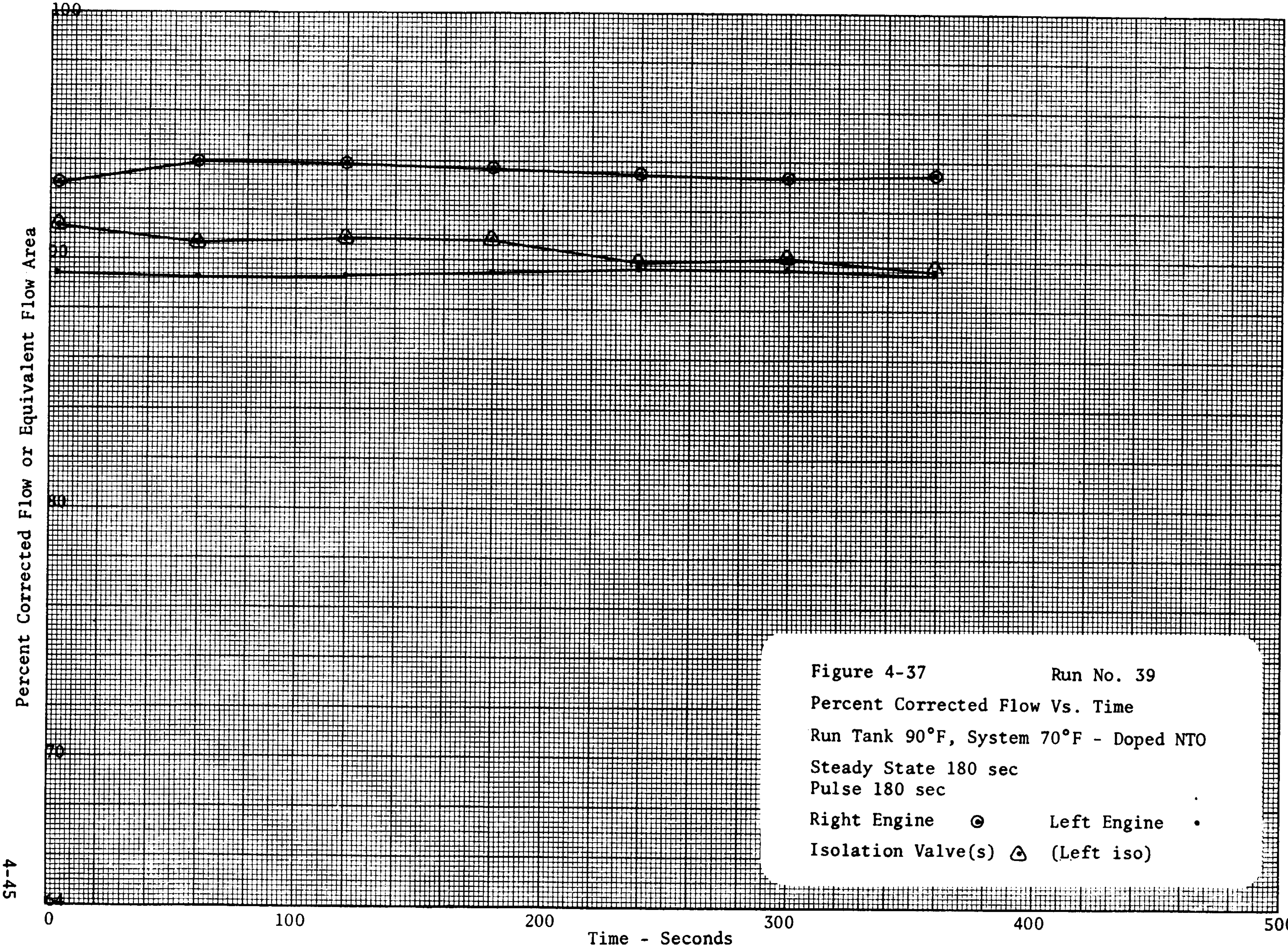


Figure 4-37 Run No. 39

Percent Corrected Flow Vs. Time

Run Tank 90°F, System 70°F - Doped NTO

Steady State 180 sec
Pulse 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Left iso)

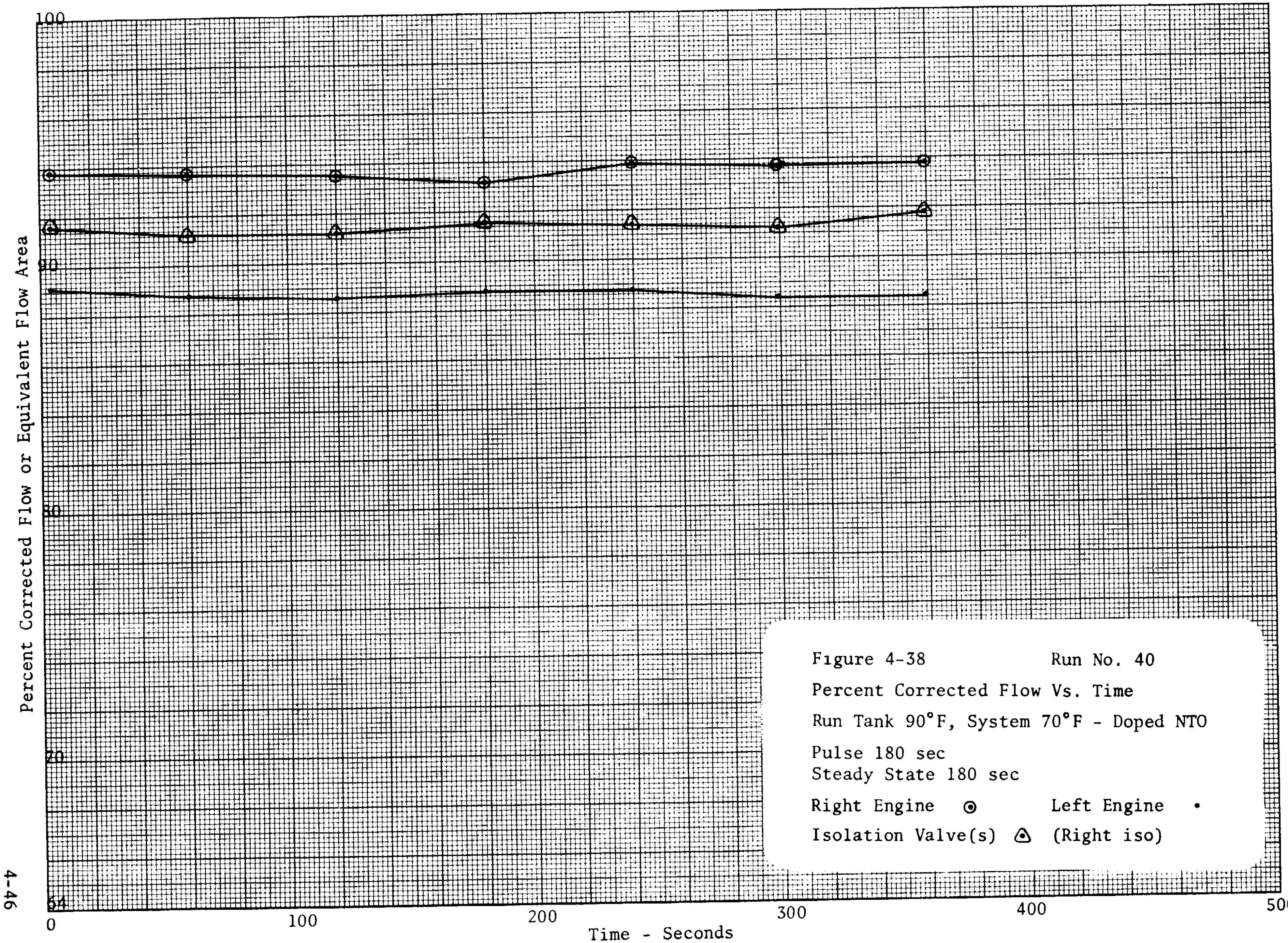


Figure 4-38 Run No. 40

Percent Corrected Flow Vs. Time

Run Tank 90°F, System 70°F - Doped NTO

Pulse 180 sec
Steady State 180 sec

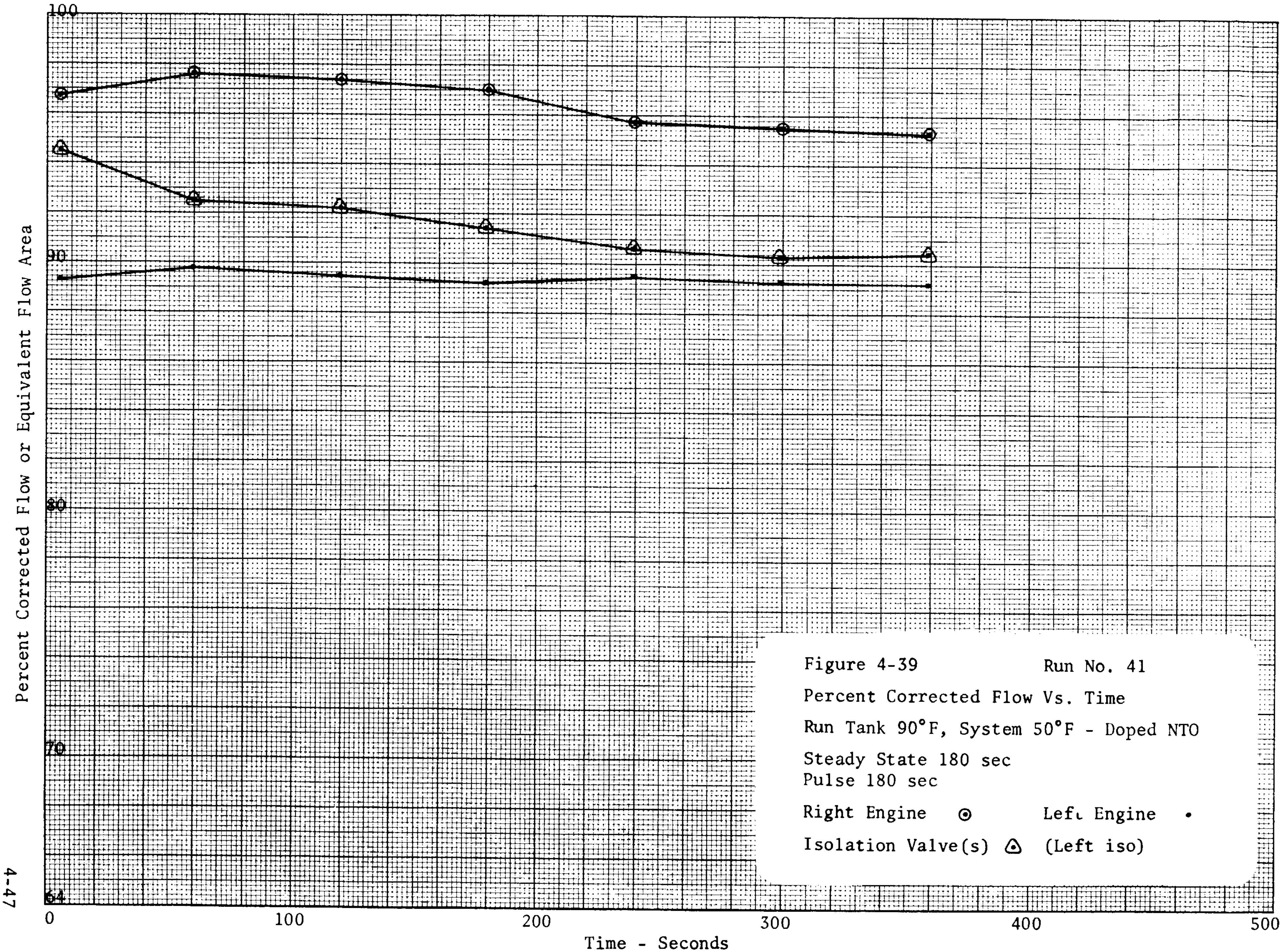


Figure 4-39 Run No. 41

Percent Corrected Flow Vs. Time

Run Tank 90°F, System 50°F - Doped NTO

Steady State 180 sec
Pulse 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Left iso)

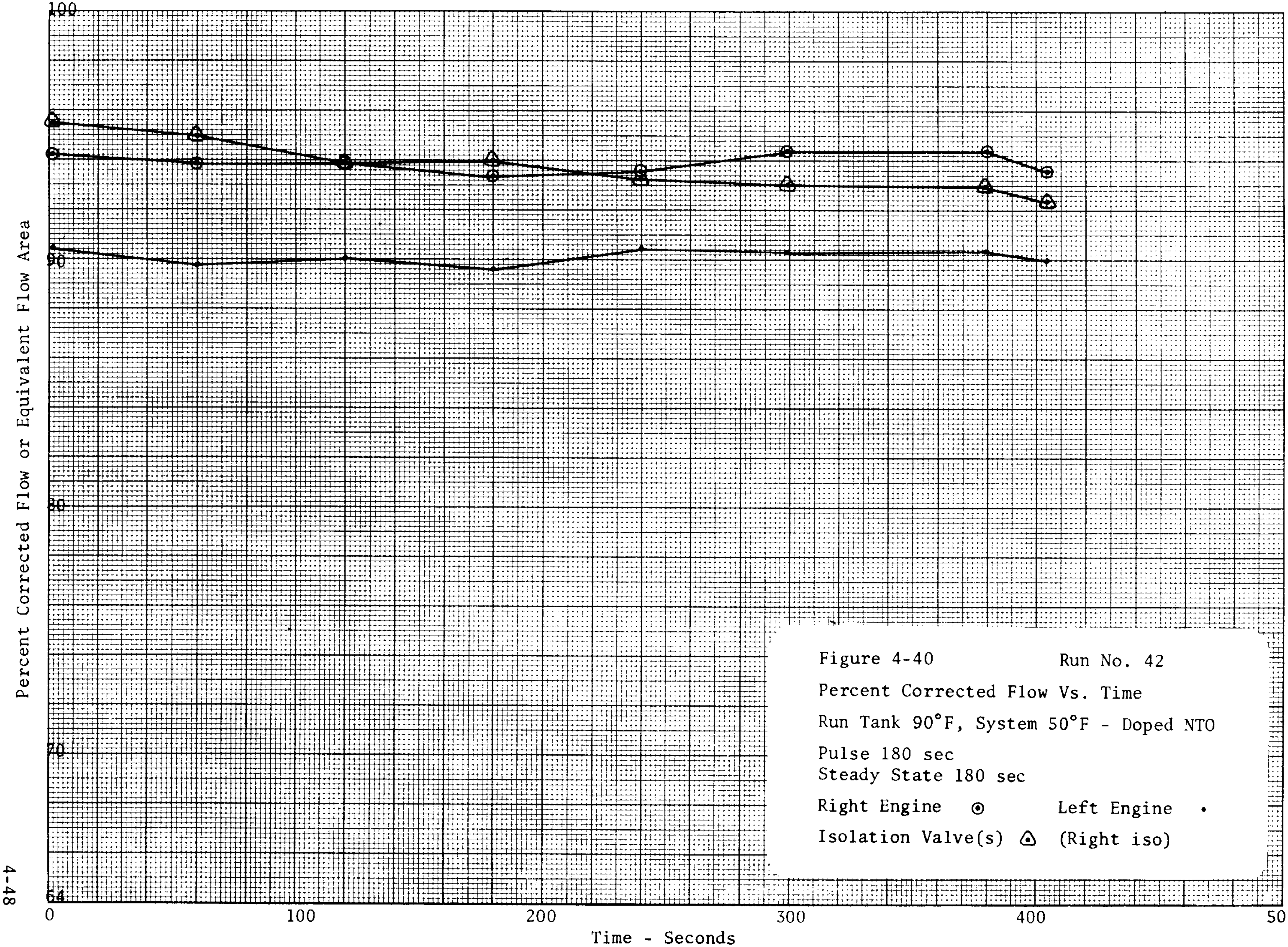


Figure 4-40
Run No. 42
Percent Corrected Flow Vs. Time
Run Tank 90°F, System 50°F - Doped NTO
Pulse 180 sec
Steady State 180 sec
Right Engine ⊙
Left Engine •
Isolation Valve(s) △ (Right iso)
Percent Corrected Flow or Equivalent Flow Area
100
90
80
70
64
Time - Seconds
0
100
200
300
400
500

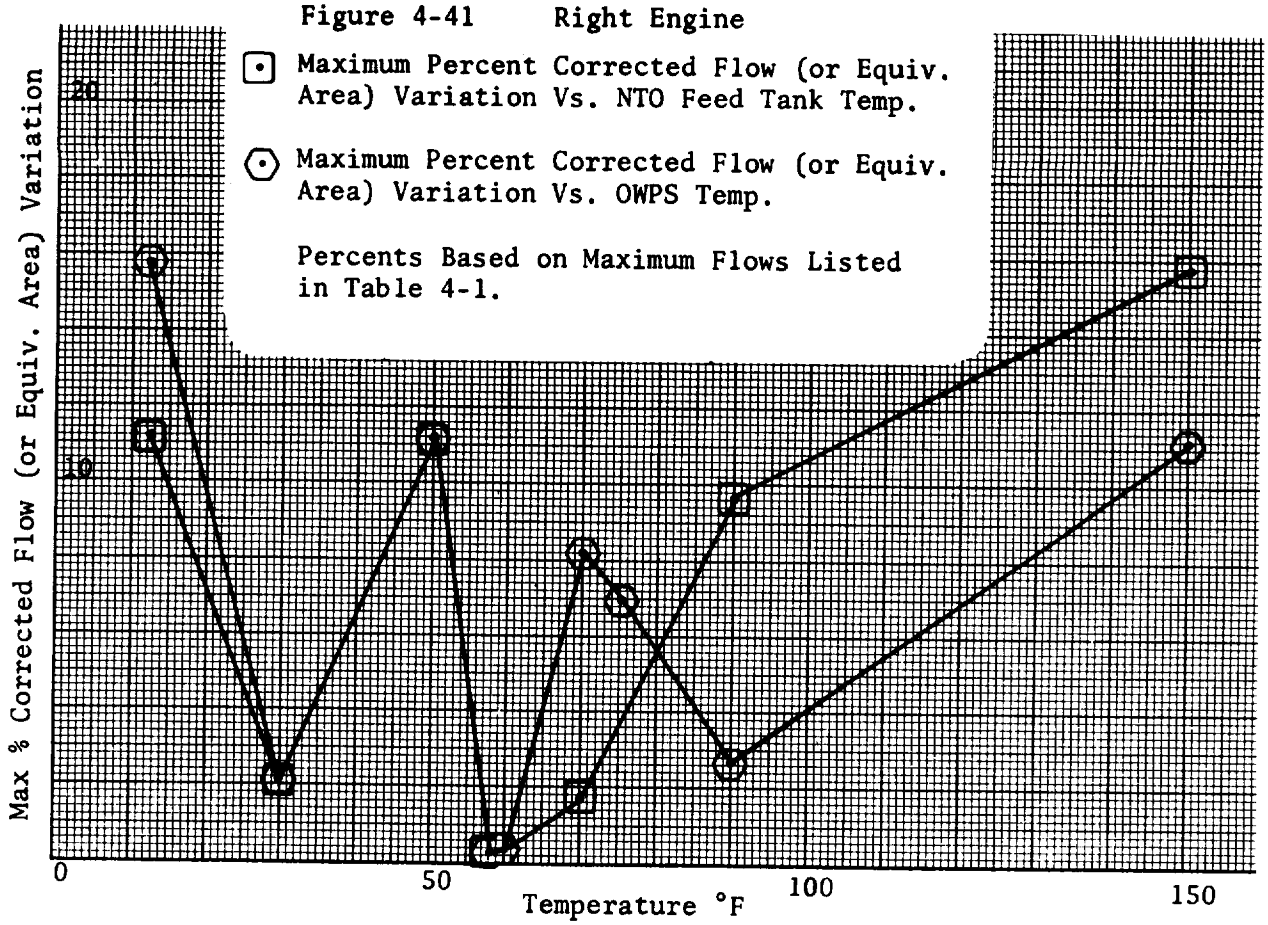


Figure 4-41 Right Engine

Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. NTO Feed Tank Temp.

Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. OWPS Temp.

Percents Based on Maximum Flows Listed in Table 4-1.

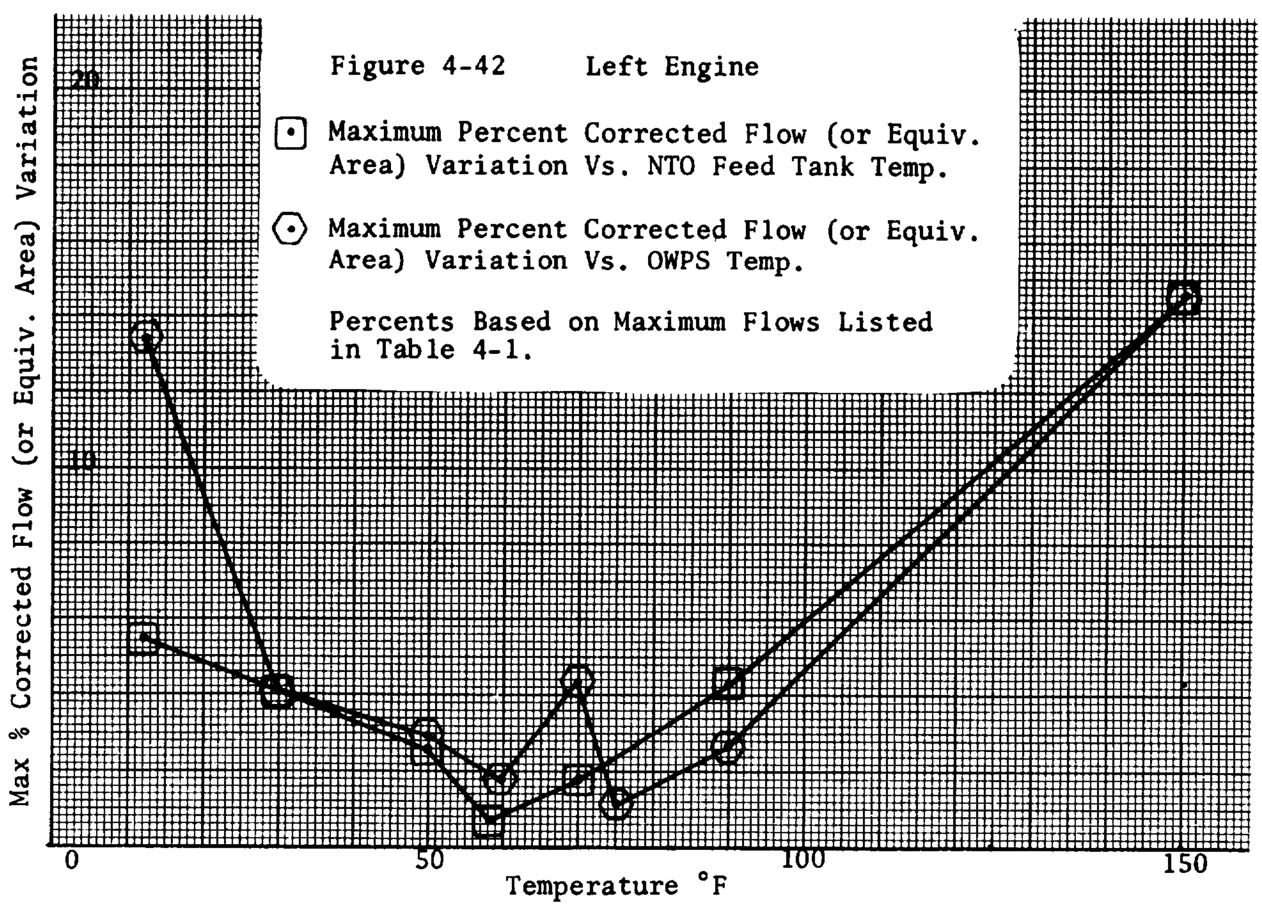


Figure 4-42 Left Engine

Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. NTO Feed Tank Temp.

Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. OWPS Temp.

Percents Based on Maximum Flows Listed in Table 4-1.

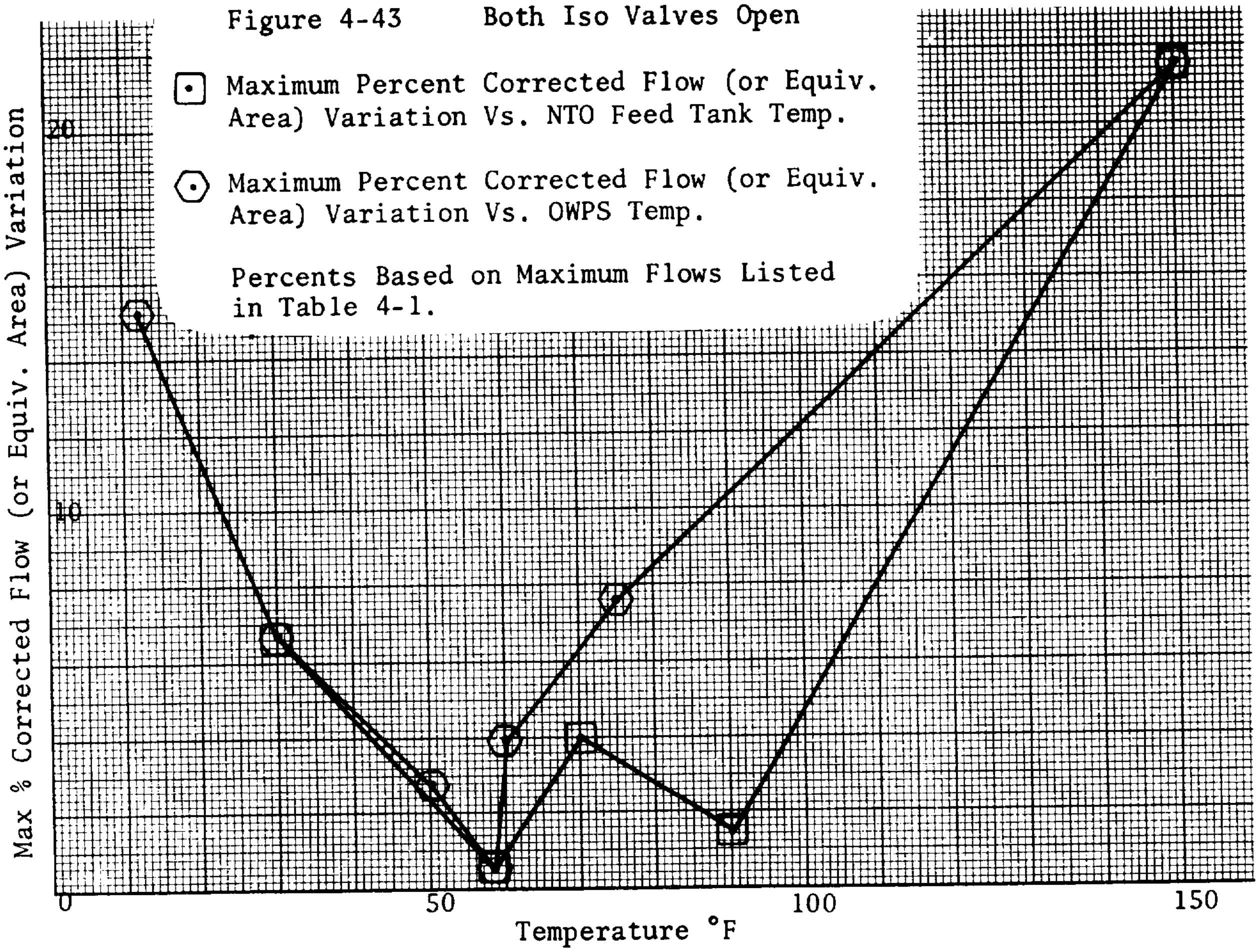


Figure 4-43 Both Iso Valves Open
Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. NTO Feed Tank Temp.
Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. OWPS Temp.
Percents Based on Maximum Flows Listed in Table 4-1.
Max % Corrected Flow (or Equiv. Area) Variation
20
10
0
50
100
150
Temperature °F

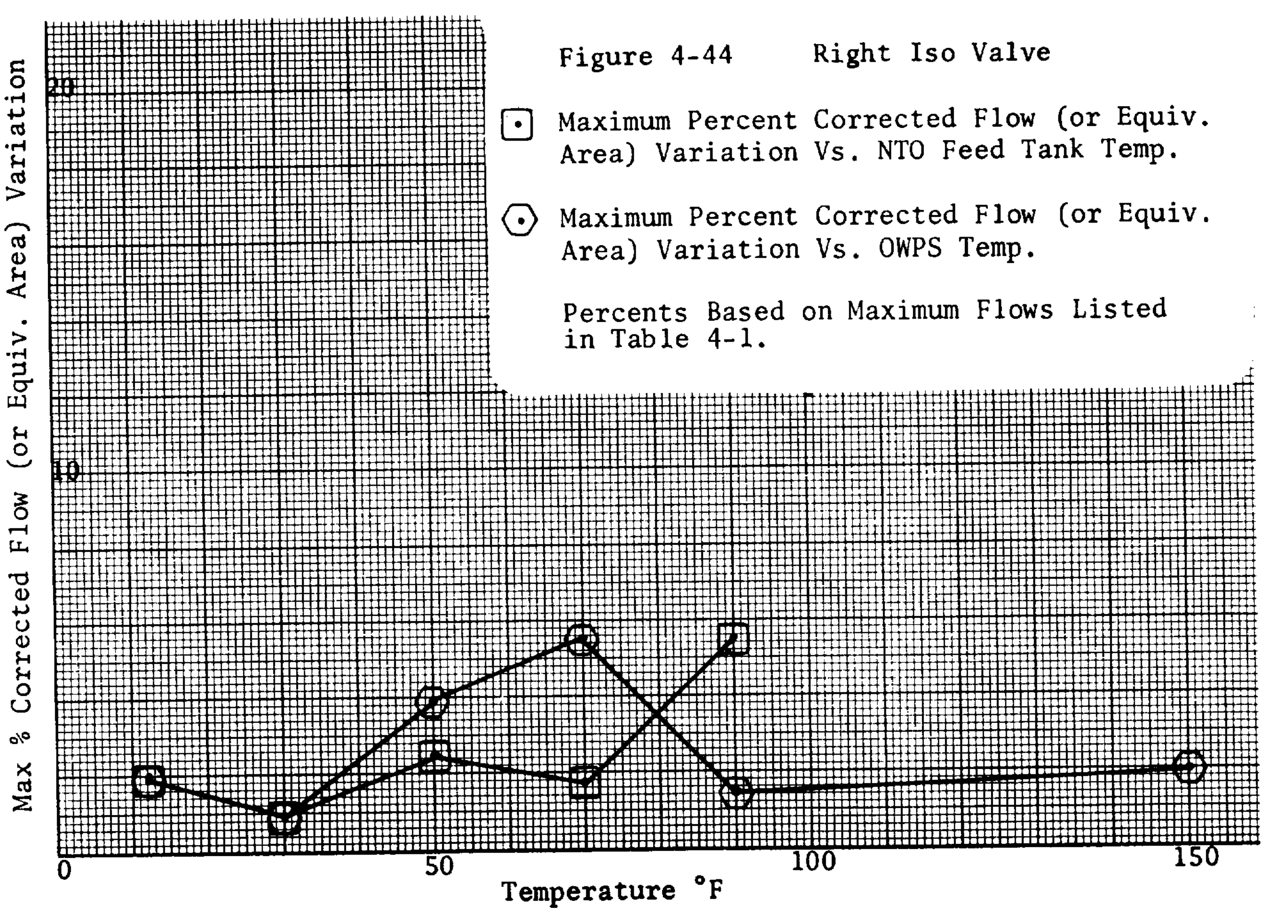


Figure 4-44 Right Iso Valve
Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. NTO Feed Tank Temp.
Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. OWPS Temp.
Percents Based on Maximum Flows Listed in Table 4-1.
Max % Corrected Flow (or Equiv. Area) Variation
20
10
0
50
100
150
Temperature °F

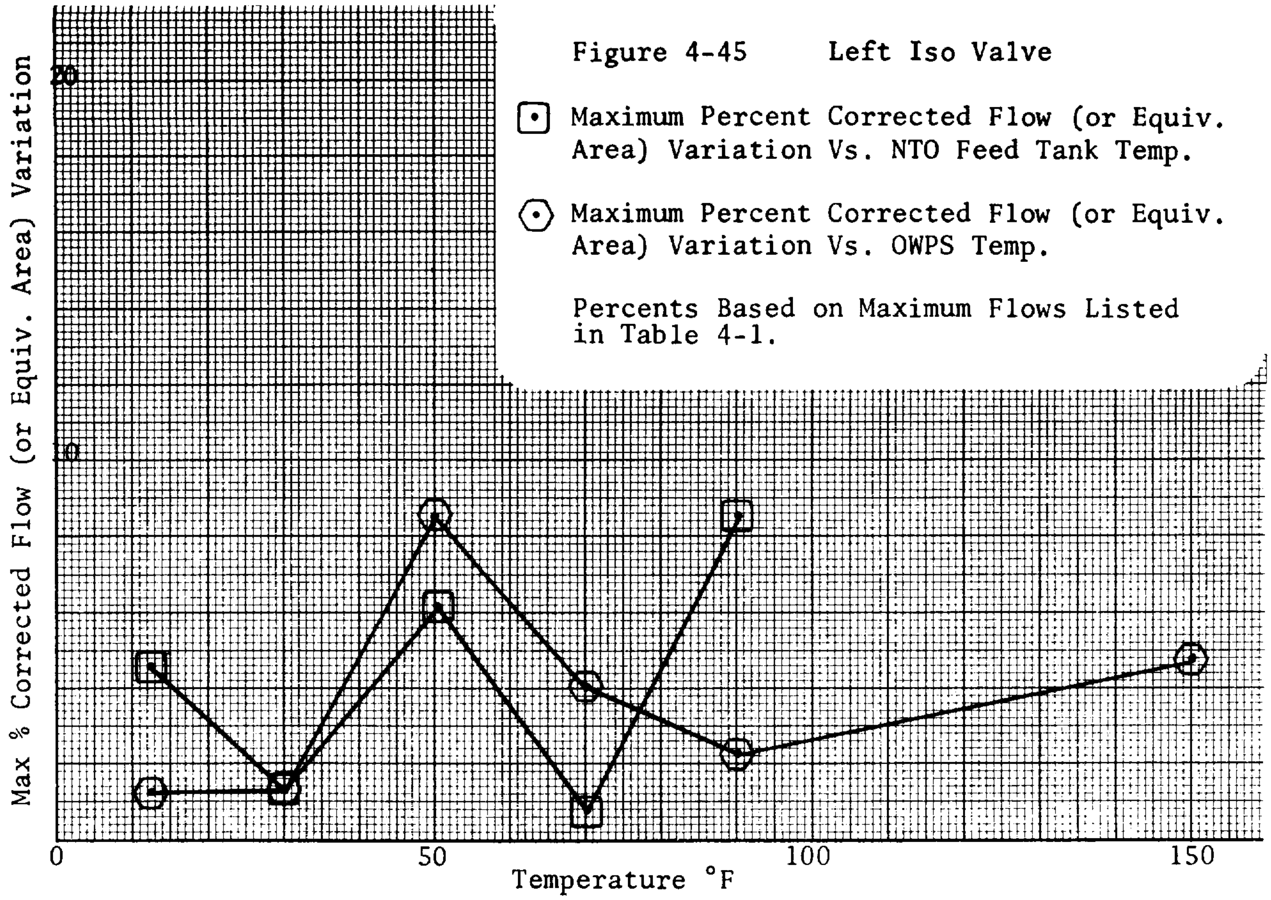


Figure 4-45 Left Iso Valve
Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. NTO Feed Tank Temp.
Maximum Percent Corrected Flow (or Equiv. Area) Variation Vs. OWPS Temp.
Percents Based on Maximum Flows Listed in Table 4-1.
Max % Corrected Flow (or Equiv. Area) Variation
20
10
0
50
100
150
Temperature °F

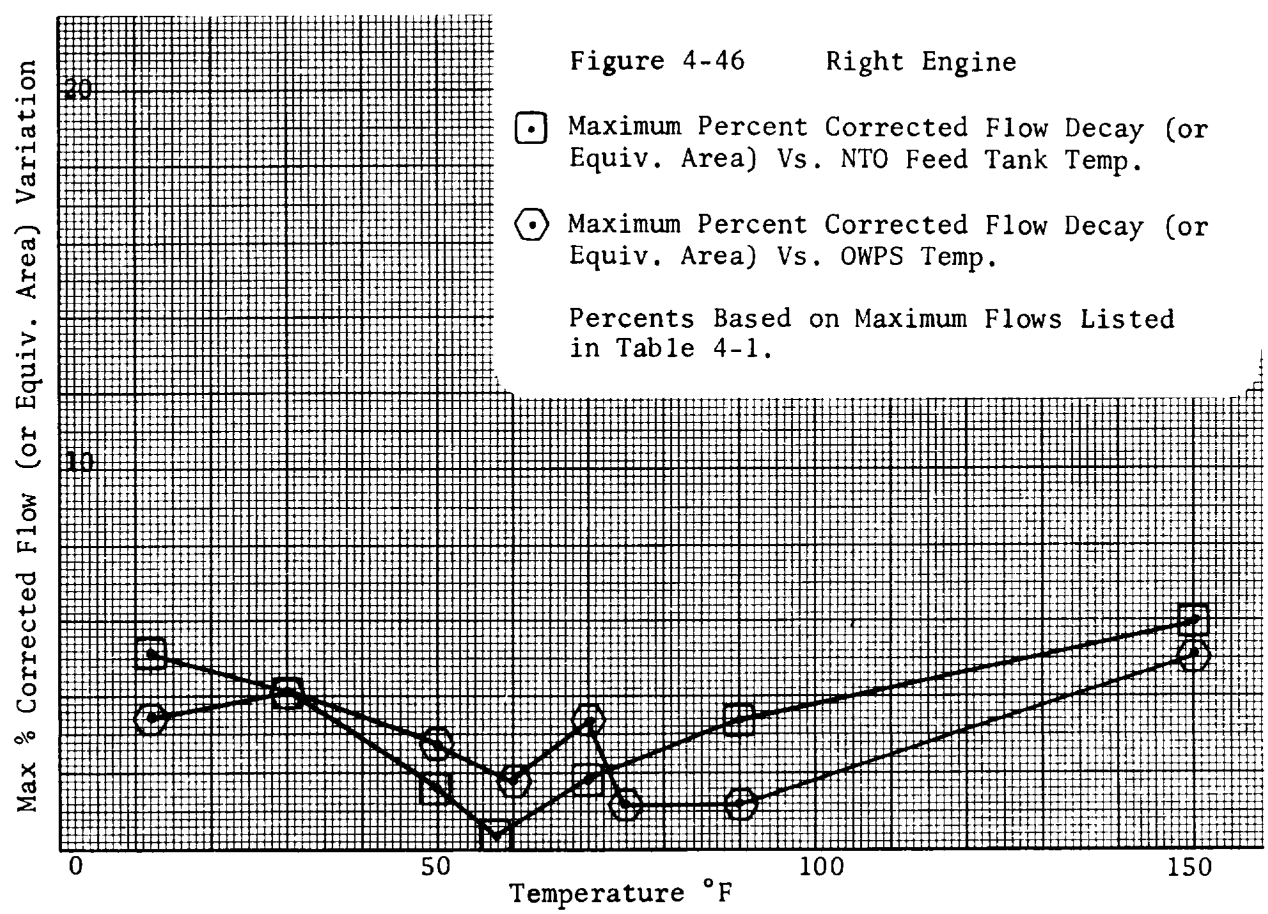


Figure 4-46 Right Engine
Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. NTO Feed Tank Temp.
Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. OWPS Temp.
Percents Based on Maximum Flows Listed in Table 4-1.
Max % Corrected Flow (or Equiv. Area) Variation
20
10
0
50
100
150
Temperature °F

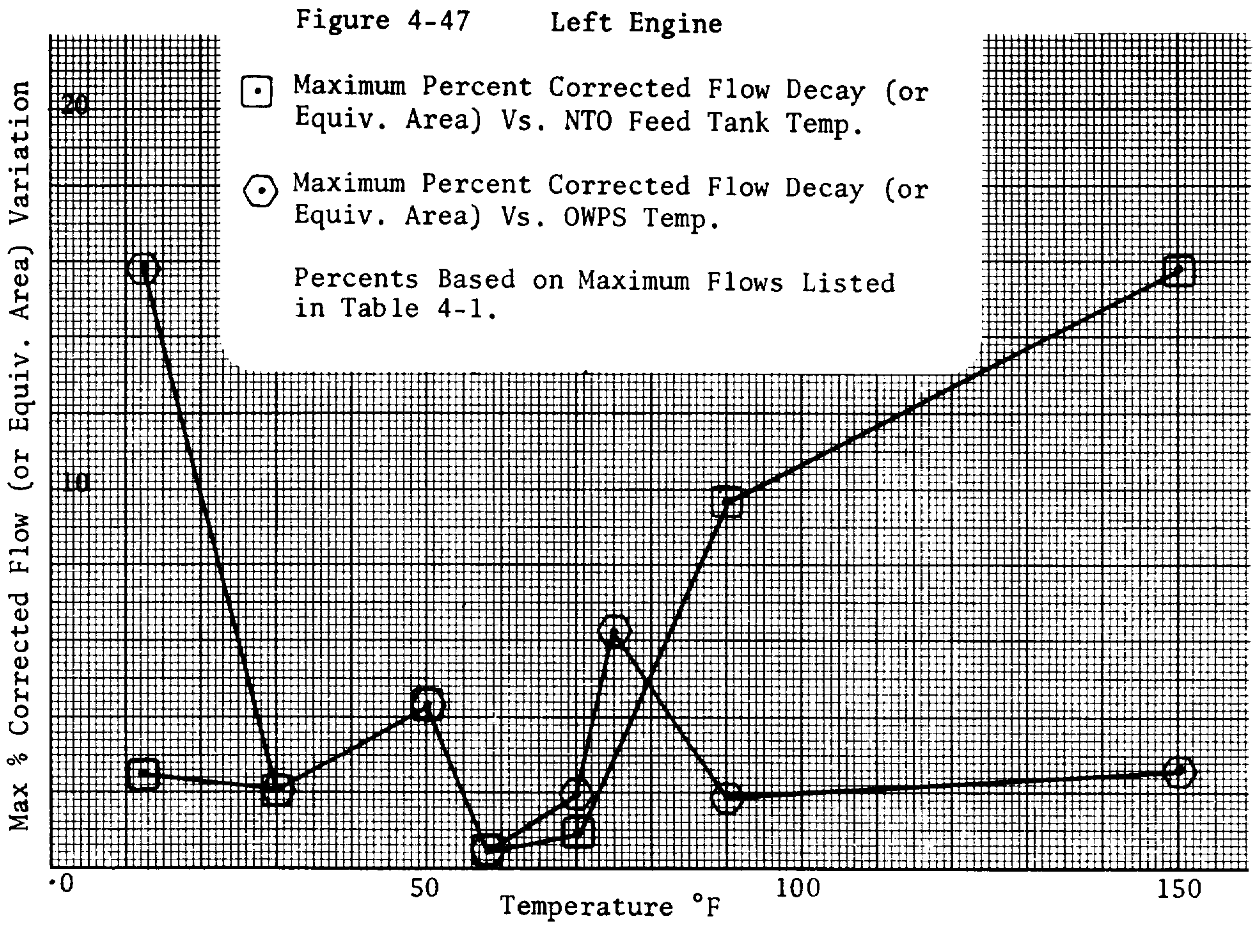


Figure 4-47 Left Engine
Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. NTO Feed Tank Temp.
Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. OWPS Temp.
Percents Based on Maximum Flows Listed in Table 4-1.
Max % Corrected Flow (or Equiv. Area) Variation
20
10
0
50
100
150
Temperature °F

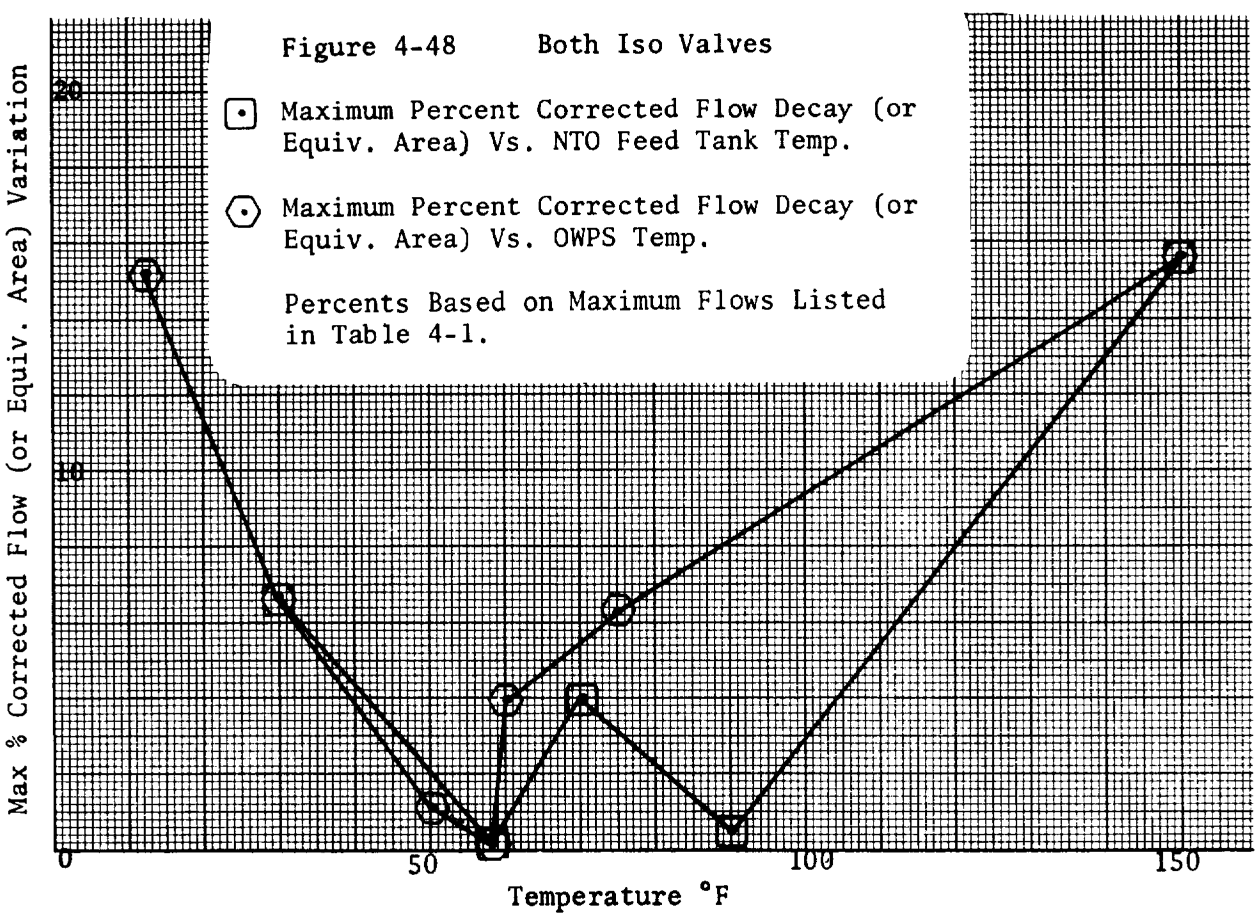


Figure 4-48 Both Iso Valves
Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. NTO Feed Tank Temp.
Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. OWPS Temp.
Percents Based on Maximum Flows Listed in Table 4-1.
Max % Corrected Flow (or Equiv. Area) Variation
20
10
0
50
100
150
Temperature °F

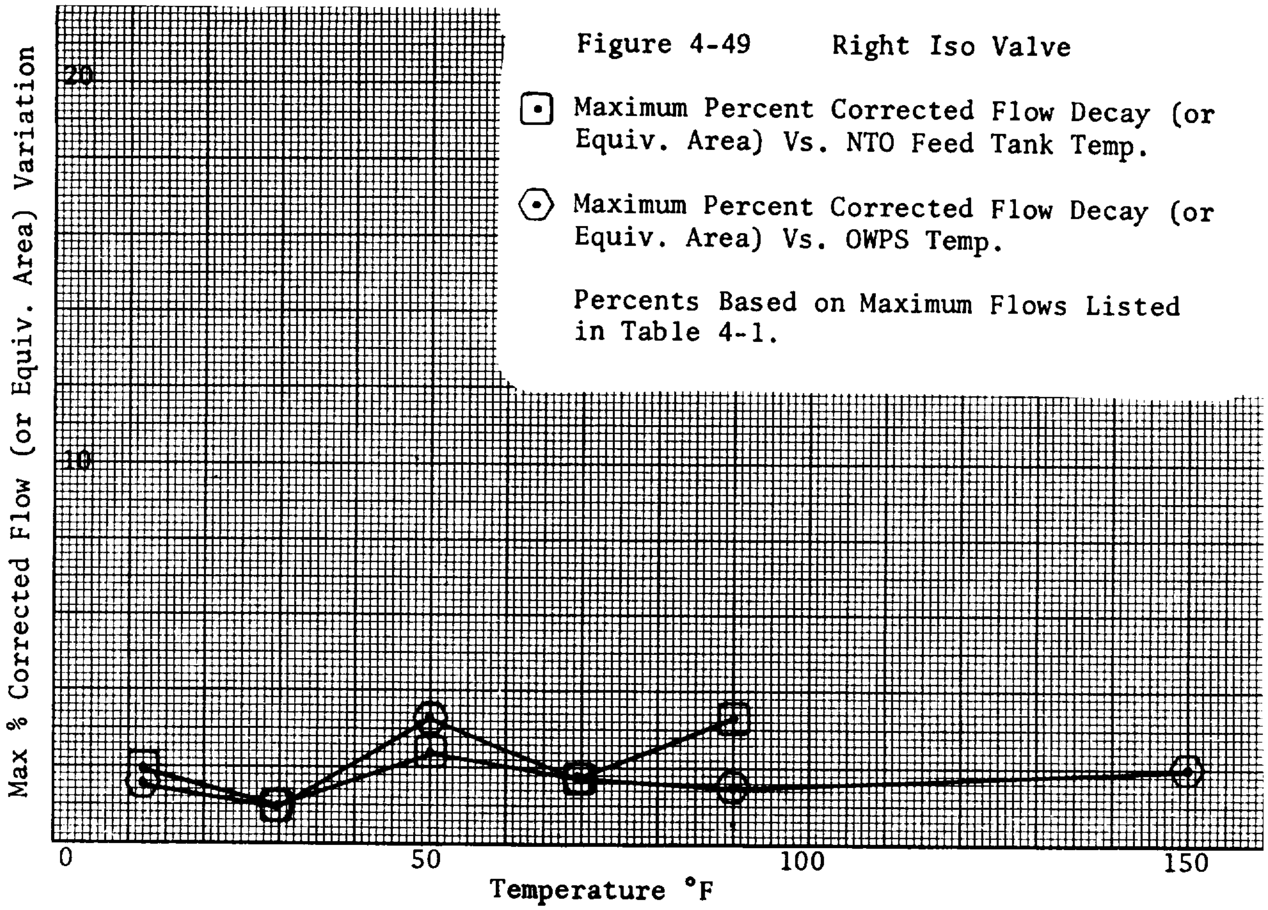


Figure 4-49 Right Iso Valve

⊡ Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. NTO Feed Tank Temp.

⨀ Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. OWPS Temp.

Percents Based on Maximum Flows Listed in Table 4-1.

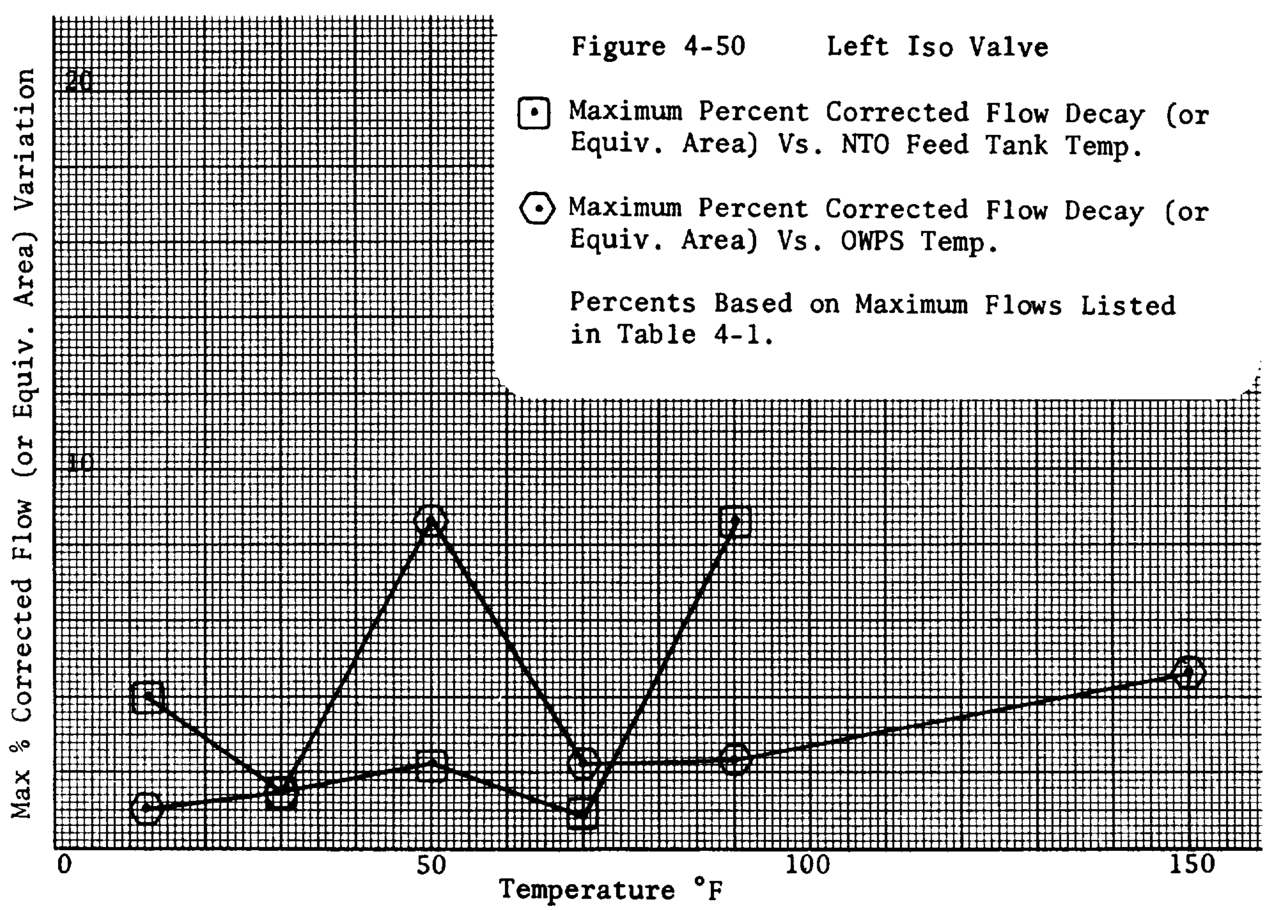


Figure 4-50 Left Iso Valve

⊡ Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. NTO Feed Tank Temp.

⨀ Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. OWPS Temp.

Percents Based on Maximum Flows Listed in Table 4-1.

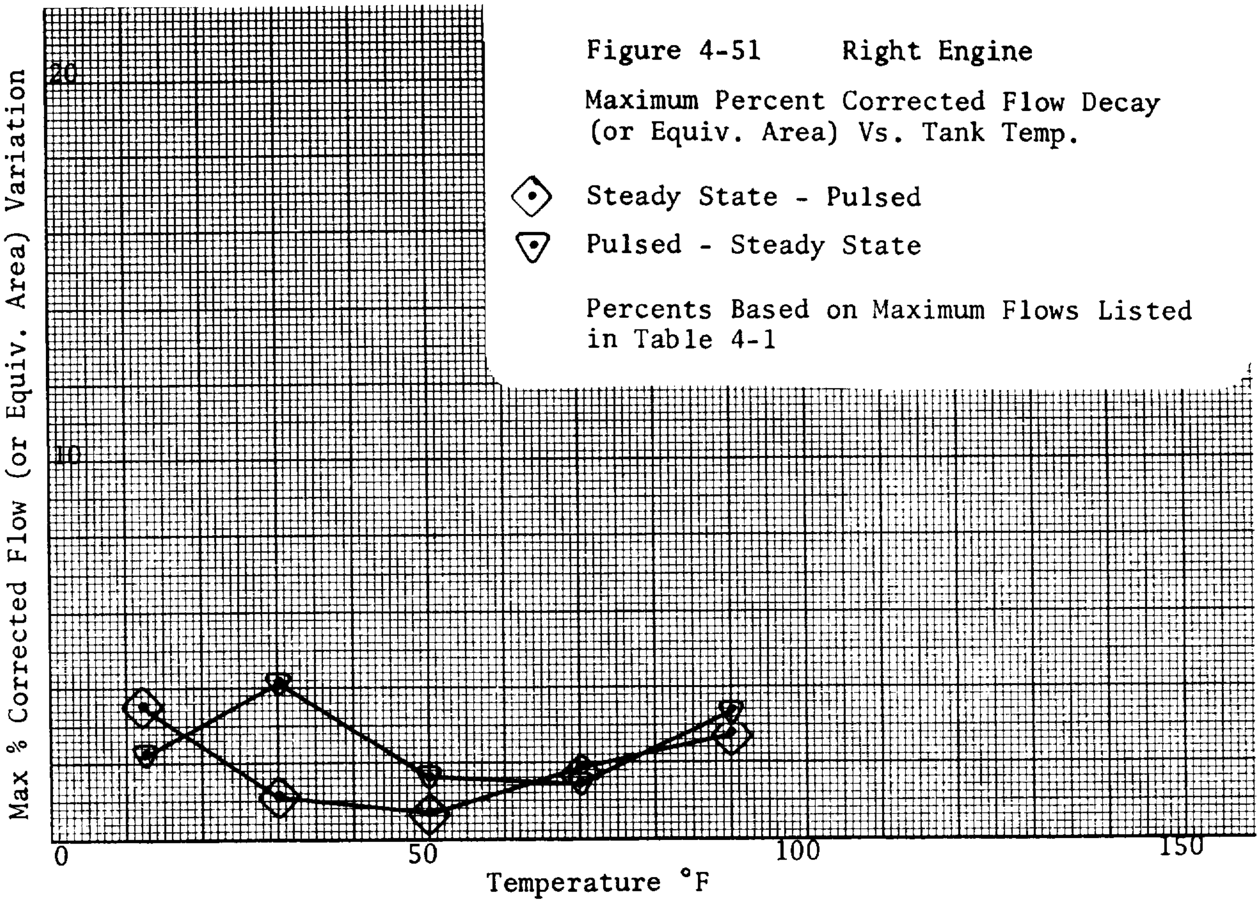


Figure 4-51 Right Engine

Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. Tank Temp.

Percents Based on Maximum Flows Listed in Table 4-1

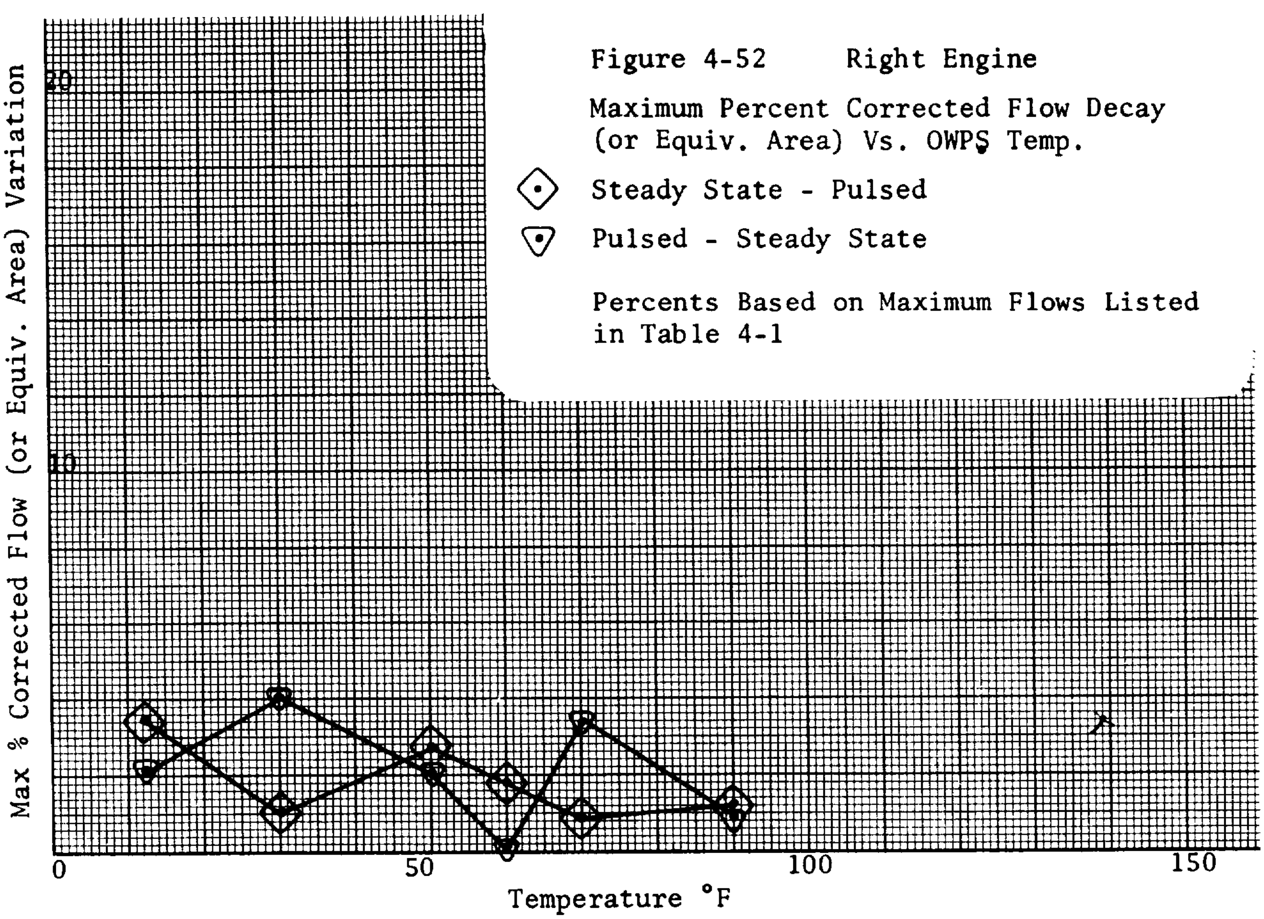


Figure 4-52 Right Engine

Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. OWPS Temp.

Percents Based on Maximum Flows Listed in Table 4-1

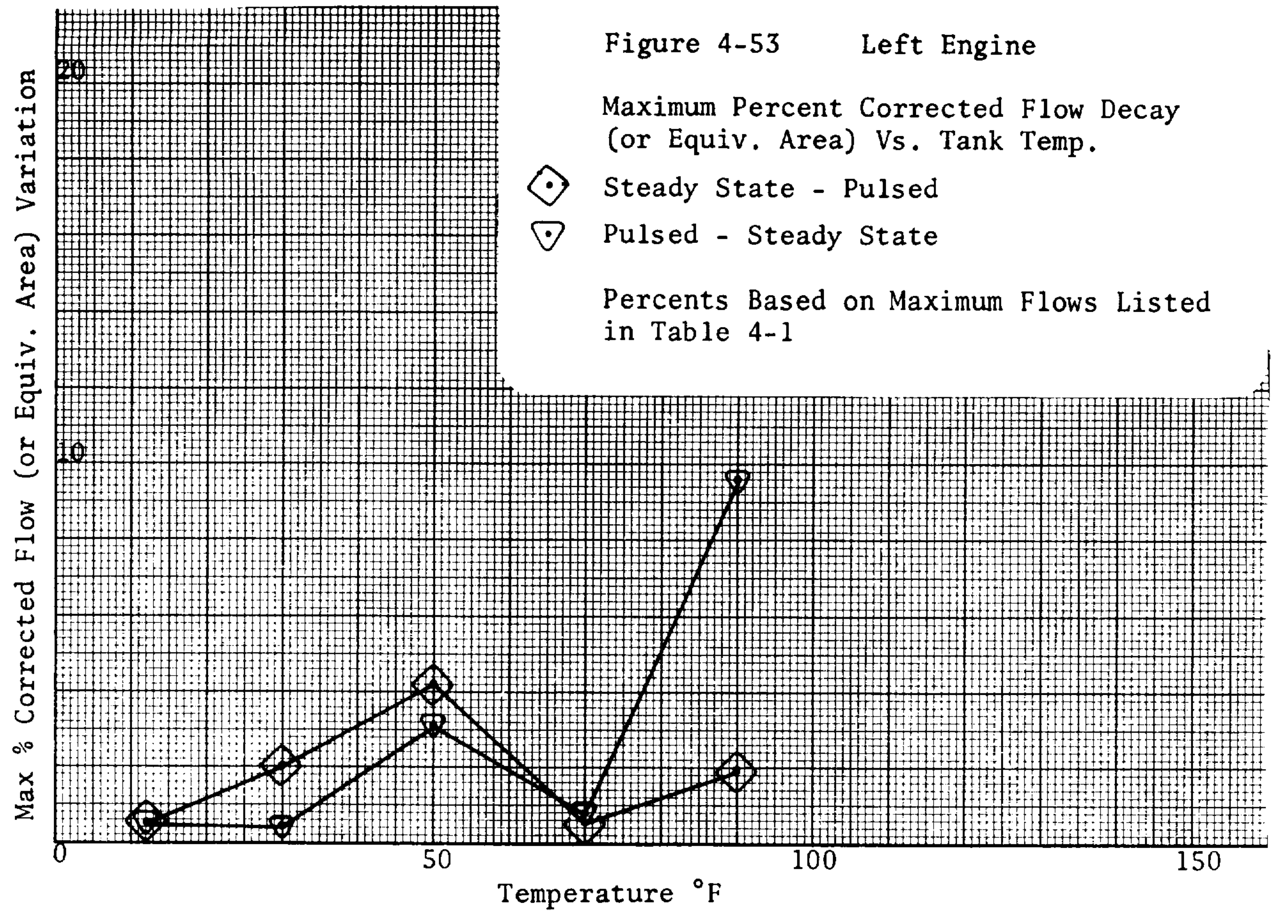


Figure 4-53 Left Engine

Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. Tank Temp.

◇ Steady State - Pulsed

▽ Pulsed - Steady State

Percents Based on Maximum Flows Listed in Table 4-1

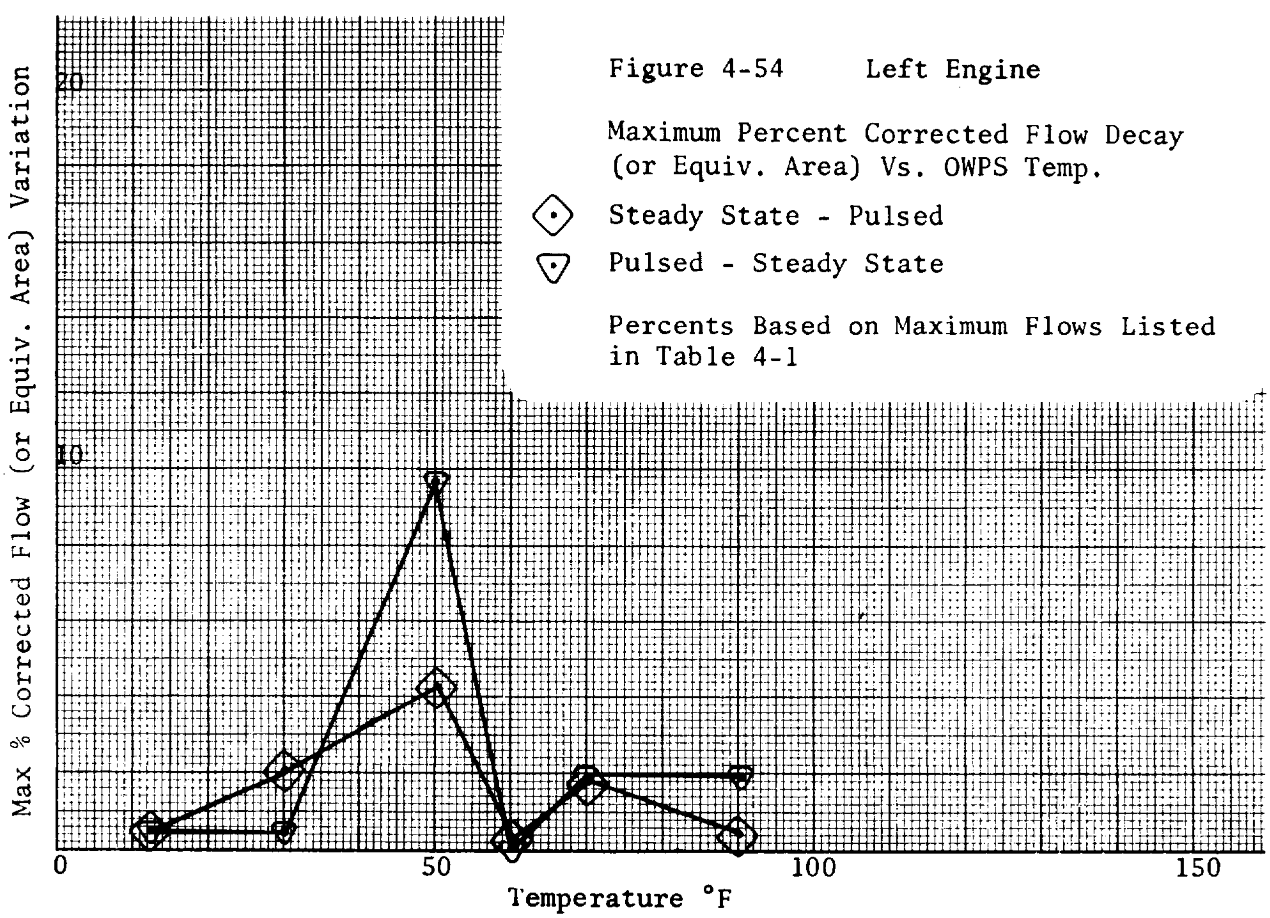


Figure 4-54 Left Engine

Maximum Percent Corrected Flow Decay (or Equiv. Area) Vs. OWPS Temp.

◇ Steady State - Pulsed

▽ Pulsed - Steady State

Percents Based on Maximum Flows Listed in Table 4-1

4.2 FLOW TEST RESULTS - CHEMICAL ANALYSES

4.2.1 Nitrogen Tetroxide Analysis

The results of the chemical analyses of nitrogen tetroxide used in the flow tests are presented in Table 4-3. All propellant loaded into the feed tank was double filtered, first through a nominal 10μ filter, and then through a nominal 5μ filter. After each filling, the filter assembly was examined for material captured by the filters during transfer. In each case, the 10μ filter had red to black-brown particulate material on the filter screen. Microscopic examination of the 5μ filter showed little or no contamination. Figures 4-55 through 4-60 are photographs of the contaminants on the 10μ filter and loose material found in the filter housing from the first two loadings. The filters were cleaned to TRW Specification PR 2-2 level 2 prior to use.

After each filling, a sample was drawn and analyzed for base point reference. Samples were taken at each temperature operating point and during selected runs where anomalous flow behavior was suspected. The sampling location was just downstream of the engine as shown in Figure 2-2.

The routine analyses of the propellant indicated that the propellant stayed within use specification over entire test sequence. Some variation in NO content was noted from the flow test specimens, but it is felt that the variation was due to an insufficient purge of some of the sample cylinders, resulting in oxidation of some of the NO to NO_2. This was corroborated by the periodic analyses of the feed tank, which indicated that little variation in NO content had occurred at the source.

The variation in particle count in both the run tank and test system indicated that the cycling temperatures and/or NTO dwell times have caused a certain amount of feed tank contamination to be built up. Of particular interest was the large build up in particle count from the first filling (sample log 54), before the feed tank had been conditioned, and the second filling (sample log 60) after the conclusion of the 150°F feed tank runs.

Table 4-3. Results of Chemical Analyses of Nitrogen Tetroxide From Run Tank and Flow Tests

Sample Location	Sample Log	Run No.	Density g/cc	N_2O_4 Assay w/w %	NO Assay w/w %	Water Equival.	Chloride or NOCl w/w %	Particulate Weight mg/l	Non-Volatile Residue mg/l: Water Soluble	Non-Volatile Residue mg/l: Acetone Soluble	Dissolved Metals Content, ppm: Fe	Ni	Cr	Cu	Particle Count: 10-25μ	25-50μ	50-75μ	75-100μ	100-250μ	>250μ/ Fibers
Run tank	54[a]	Tank fill	1.420	99.25	0.62	0.05	0.02	0.5	29.0	N.A.	4.4	1.1	N.A.	2.3	60	18	4	2	4	0/0
Run tank	60[a]	Tank fill	N.A.	98.76	0.70	0.08	0.015	1.0	13.5	258.5	1.6	1.0	N.A.	0.8	4,000	3,040	1,040	162	108	10/3F
Run tank	74	Tank fill	1.423	99.13	0.58	0.11	0.006	<0.5	16.5	27.5	1.6	0.3	0.6	nil	1,050	592	109	105	92	6/3F
Run tank	83	Tank anal.	1.420	99.21	0.56	0.11	0.011	1.5	1.5	31.5	1.4	<0.1	nil	4.7	2,500	950	310	149	77	4/1F
Run tank	84	Tank fill Art. Aged NTO	1.420	99.29	0.59	0.11	0.005	0.5	30.5	19.5	0.3	nil	<0.1	1.2	700	450	155	26	22	1/2F
Left eng.	53	1			0.45	0.10		N.A.												
Right eng.	55	2			0.35	0.09		N.A.												
Left eng.	56	3			0.51	0.09		N.A.												
Left eng.	57	5			0.46	N.A.		N.A.												
Right eng.	58	6			0.30	0.09		1.0			2.7	0.1	nil	13.2	1,832	988	150	12	26	3/3F
Left eng.	59[a]	7			0.67	0.10		1.5	7.0	22.5	29.5	N.A.	N.A.	1.7	1,425	425	175	38	35	10/6F
Left eng.	61	9			0.66	0.10		2.5												
Right eng.	62	12			0.64	0.09		0.5												
Left eng.	63	15			0.61	0.11		1.5							1,195	560	108	15	12	0/2F
Left eng.	64[a]	17			0.61	0.11		1.0	28.8	38.4	3.5	0.4	0.2	0.6						
Right eng.	65	18			0.41	0.11		N.A.												
Right eng.	66	19			0.62	0.11	0.009	<0.5	0.5	1.0	0.9	0.3	0.4	nil						
Right eng.	75	20			0.53	0.11		10.5												
Left eng.	76	22			0.53	0.11		0.5												
Right eng.	77	24			0.61	0.11		3.5												
Left eng.	78	26	1.420	99.43	0.54	0.12	0.007	5.5	10	17.5	2.6	0.3	<0.1	1.3	190	48	15	24	5	1/3F
Right eng.	80	29			0.42	0.11		3.5												
Left eng.	81	31			0.42	0.11		3.0	4.0	9.0	1.7	<0.1	nil	0.4						
Left eng.	86	33[b]			0.47	0.11		0.5			1.1	nil	nil	0.5						
Right eng.	87	35[b]			0.39	0.11		4.0			0.8	0.6	nil	0.4						
Left eng.	88	37[b]			0.41	0.11		0.5			4.4	0.7	nil	1.5						
Right eng.	89	39[b]			0.38	0.12		0.5			2.4	0.3	nil	2.1						
Left eng.	90	41[b]			0.42	0.11		1.0			2.9	nil	0.9	1.0						
Right eng.	91	42[b]			0.34	0.11		0.5			0.4	0.2	0.2	0.8						

a Samples for dissolved metals content were not filtered before analysis.

b Artificially aged NTO test runs.

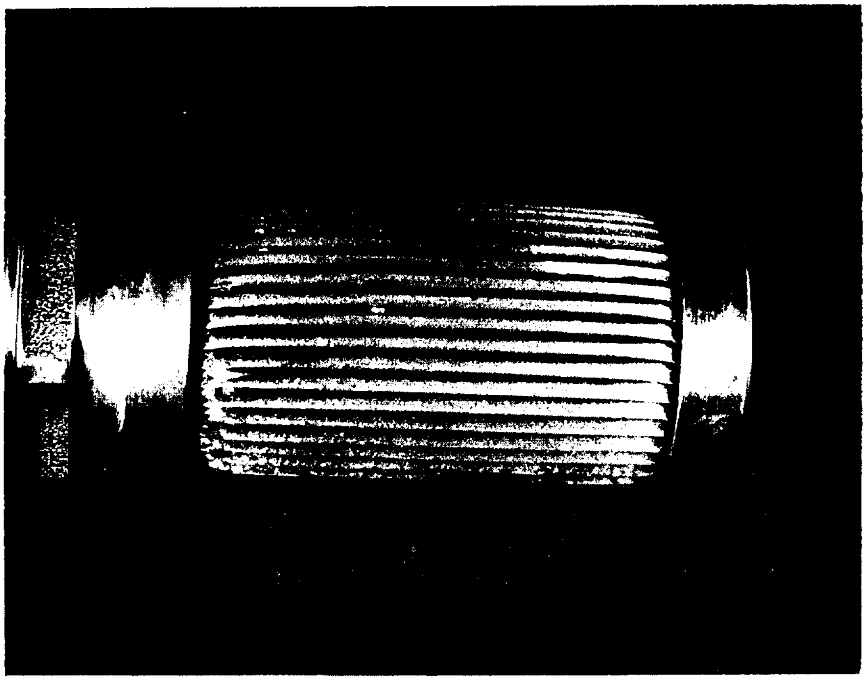


Figure 4-55. Photograph of Nominal 10μ Filter After First Propellant Loading (Approx. Magnification: 1X)

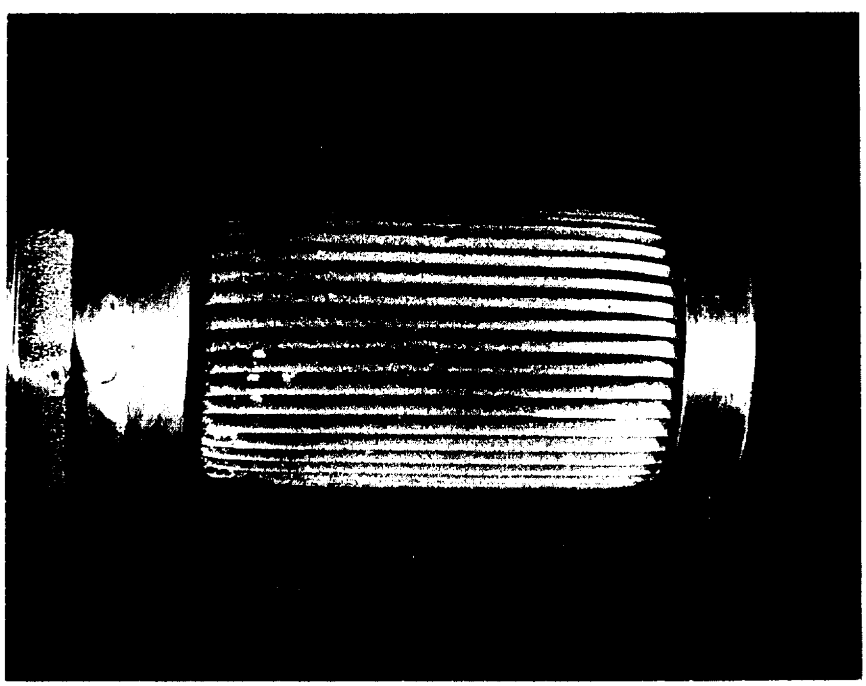


Figure 4-56. Photograph of Nominal 10μ Filter After First Propellant Loading (Approx. Magnification: 1X)

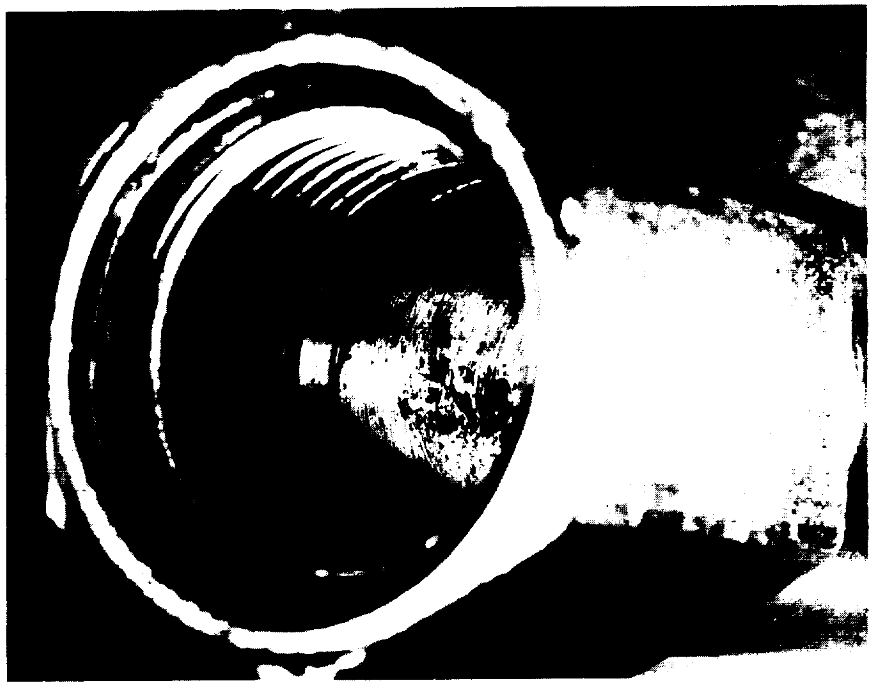


Figure 4-57. Photograph of Filter Housing After First Propellant Loading (Approx. Magnification: 2X)

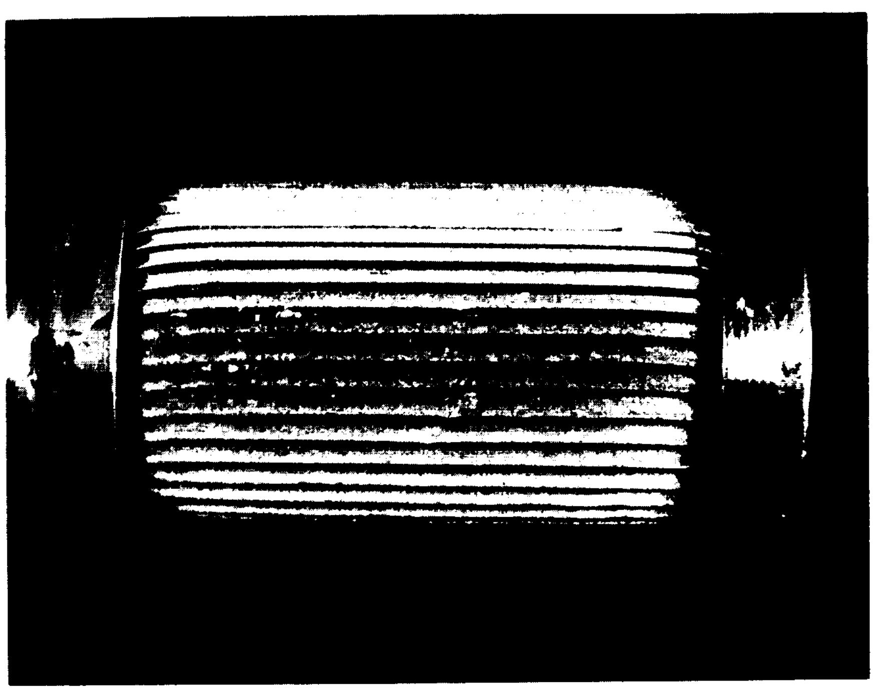


Figure 4-58. Photograph of Filter After Second Propellant Loading (Approx. Magnification: 1.5X)

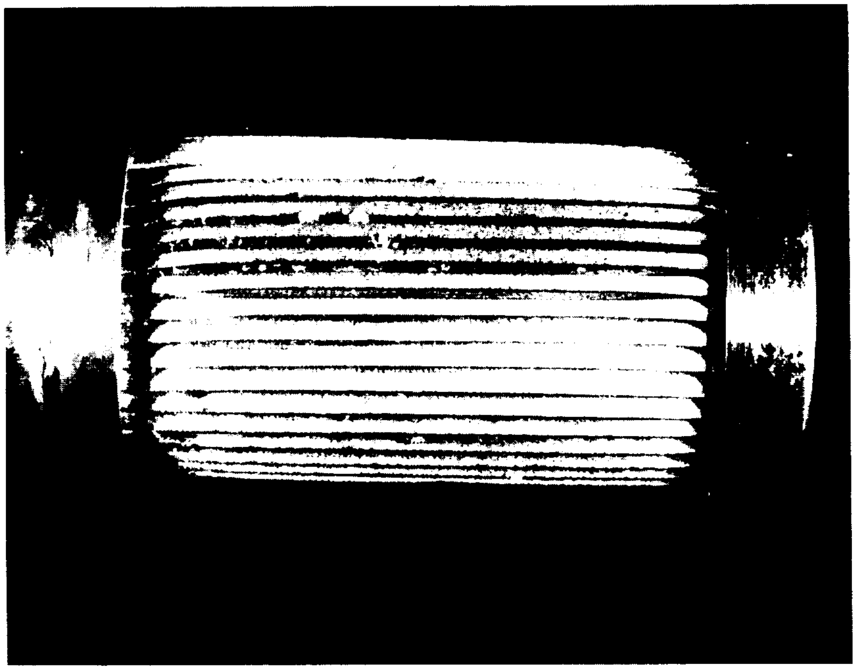


Figure 4-59. Photograph of Filter After Second Propellant Loading (Approx. Magnification: 1.5X)

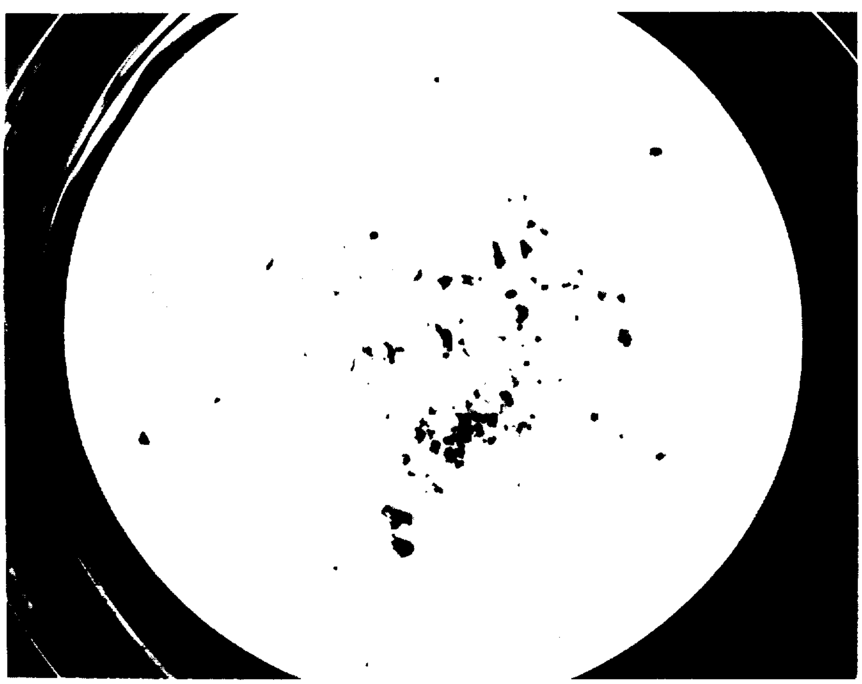


Figure 4-60. Photograph of Material From Filter Housing After Second Propellant Loading (Approx. Magnification: 1.5X)

The particle count became lower on successive fills, since the feed tank was nominally conditioned only between 30°F and 90°F. It is felt that this behavior simulates the contamination mechanism which might exist in the actual OWPS nitrogen tetroxide storage tank.

4.2.2 NTO Contamination Analysis

Because of the large flow variations experienced in the 150°F and the 12°F feed tank runs, the test system was dismantled after each series of runs, the trapped NTO drained and filtered, and each component backflushed with Freon TF. The residue was caught on Millipore filter paper. Table 4-4 illustrates the particulate weights found in the test system after each run series. Figure 4-61 shows the filter pad from sample point 7(b).

The filter from sample point 7(a) was scraped and the residue analyzed by a micro KBr infrared technique. The spectra obtained gave an indication of OH^- and NO_3^- anions and indicated that the residue consisted mainly of hydrated metal nitrate salts. Sample points 1, 3, 6 and 7(b) were analyzed by X-ray fluorescence and infrared techniques. The infrared analyses again indicated metal nitrate salts. X-ray analyses identified iron in all samples, plus chromium in sample point 3(b) and chromium, nickel, and zinc in sample point 7(b).

The second phase liquid found at sample points 6 and 7(a) was dissolved in water and analyzed for metal content by atomic absorption spectroscopy. The results are presented in Table 4-5. The numbers are indicative of relative amounts only since the initial sample sizes were not known. Analysis of the samples by the Brucine method gave a positive nitrate test, thus, the materials were probably metal nitrates.

In addition to the contaminants found in the OWPS test system, special analyses were performed on the acetone soluble NVR samples from sample log numbers 60 and 64 and on the particulate weight filter paper from sample log 75.

Table 4-4. Particulate Weights from Disassembled Test System Components and Trapped Nitrogen Tetroxide

	Sample Point	Particulate Weight, mg[a]	Particulate Weight, mg[b]
1.	Backflush from first filter	0.1	0.7
2.	Backflush from isolation valves	1.9	1.1
3.	Backflush from second filter	0.2	1.1
4.	Backflush from right engine	0.4	0.2
5.	Backflush from left engine	0.5	0.1
6.	N_2O_4 from first filter inlet part	3.4[c]	2.5
7.	Combined N_2O_4 from engine inlets	2.4[c]	2.3[d]
8.	N_2O_4 from downstream of both engines	---	0.4[c]

[a] From runs culminating in 150°F feed tank to 12°F test system

[b] From runs culminating in 12°F feed tank to 12°F test system

[c] Transparent globules of a second phase liquid found in the N_2O_4. The second phase was insoluble in N_2O_4 or Freon but was soluble in water.

[d] As c, except additional tan colored residue on filter.

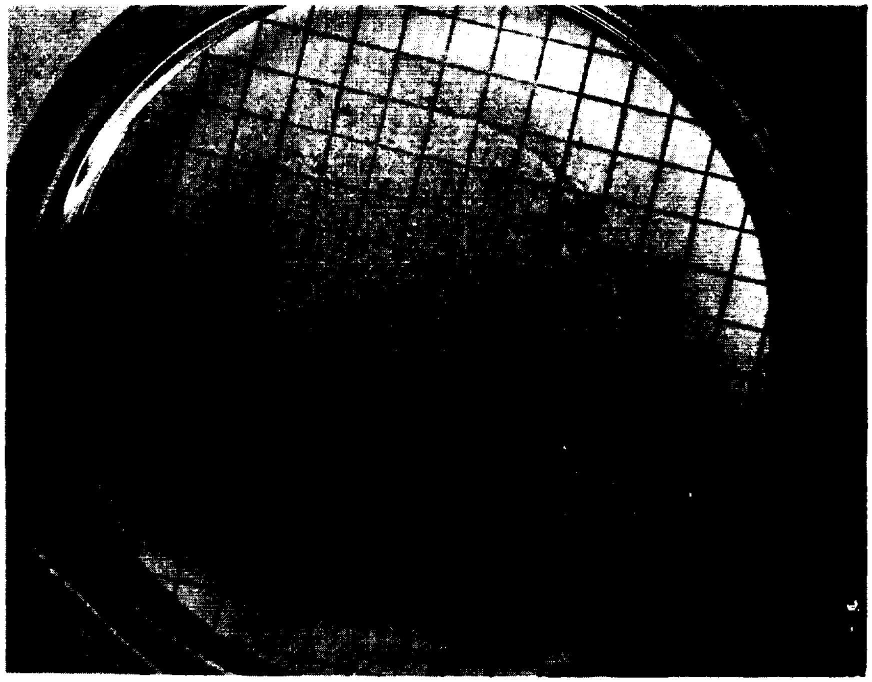


Figure 4-61. Filtered Residue from Sample 7(b)
(Approx. Magnification: 2X)

Table 4-5. Analysis of Nitrogen Tetroxide Insoluble Liquid Found in OWPS Test System

Sample	Metals, μg				
	Fe	Ni	Cr	Cu	Zn
6(a), N_2O_4 insolubles from first filter inlet part	125	165	45	10	44
7(a), N_2O_4 insoluble from right engine (a)	162	37.5	33	7.5	31
7(a), N_2O_4 insolubles from left engine (a)	5.0	17.5	12.5	5.0	42.5

(a) N_2O_4 portion combined for total sample point 7(a) in Table 4-3.

The acetone soluble NVR samples were analyzed by infrared spectroscopy. The resultant spectra consisted of organic constituents and nitrates which may or may not be organic in nature. The organic portion gave indications of alkyl, aryl, hydroxyl, and carboxylic acid groups.

The filter pad from sample log 75, which had the highest particulate weight found, was first analyzed by X-ray fluorescence, and showed an indication of iron. The pad was then cut in half and the two sections rinsed with water and isopropanol, respectively.

The alcohol rinse gave an infrared spectrum which correlated to the spectra obtained from the NVR residues. The water rinse produced a red-brown residue which yielded an infrared spectrum indicative of a nitrated metal salt.

Since the results from the NVR and particulate weight analyses from various samples of NTO were similar, it is indicated that the NVR material, in particular the organic components, may saturate (under certain conditions) to such an extent that some of the material may be suspended in the NTO, as well as being in solution, and aggregate into particles larger than 10μ under operating conditions and temperatures. Since NVR contaminants have been found in fresh specification grade propellant in concentrations varying from 50 mg/l to 350 mg/l (Reference 2), the origin of the material is uncertain.

4.2.3 Analysis of the Crystalline Material

In an attempt to determine the nature and formation of the crystalline material found in the compatibility tests as described in Section 4.4, and to elucidate the flow anomalies found in the 12°F feed tank to 12°F or 150°F system runs, a series of experiments were performed on both specification nitrogen tetroxide and the one sample (sample log 58) that had the highest indicated copper content. There were two types of crystals formed upon cooling the NTO, these were white and blue-green in color.

The blue-green crystals were formed at 1°C above the freezing point of NTO, and would not redissolve upon rewarming the solution to 55°C. The crystals were collected by filtration and analyzed by atomic absorption and infrared spectroscopy. These crystals were extremely deliquescent and were analyzed as an aqueous solution. Atomic absorption analysis gave 47.6μ g of copper, correlatible to the estimated amount of original sample collected. Infrared spectra indicated only the presence of nitrates. From the analyses, and the original color of the crystals, it is concluded that the contaminant was anhydrous cupric nitrate. It has been noted, however, that $Cu(NO_3)_2 \cdot N_2O_4$ has been prepared (Reference 14), thus the material may have had NTO coordinated to the parent compound. Other than the small amount noted in the compatibility tubes, all other attempts to obtain similar material from samples other than sample log 58 were unsuccessful.

The white crystalline material was obtained at -11.7°C (the total solution freezing point was -12.7°C). These crystals redissolved upon warming, and were collected by decanting the supernatent NTO at -12.0°C. The crystals, upon melting, turned into a dark brown liquid and were analyzed for comparison with the starting material. The comparative analysis is given in Table 4-6. Infrared spectrophotometric scans of the material and specification grade NTO gave essentially identical spectra.

The analyses performed on the white crystalline material tend to disprove the theory that the material is either a ternary phase of HNO_3, H_2O, and NO, or a binary phase of HNO_3 and HNO_2, but rather indicate a phase of nitrogen tetroxide. The presence of active nucleation sites in NTO could cause the nitrogen tetroxide to freeze at a temperature higher than the normal freezing point, however, the source or composition of the nucleating material is unknown at this time, and while the precipitation of a white crystalline material has been observed before at TRW Systems Group, this phenomena presently seems random in occurrence.

Table 4-6. Comparison of MSC-PPD-2 Nitrogen Tetroxide and the Higher Freezing Point White Crystals

Analysis	Starting NTO	Higher Freezing Crystals
N_2O_4 assay, % w/w	99.21	99.28
Chloride as NOCl, % w/w	0.011	0.007
NO content, % w/w	0.56	0.47
Metals, ppm		
Fe	1.5	0.8
Ni	0.4	nil
Cr	nil	0.2
Cu	4.6	3.0

4.3 NITROGEN TETROXIDE AGING STUDY RESULTS

Analysis of the NTO before cycling showed that the propellant was in specification, with a nominal dissolved metal content. After aging, the iron, nickel, and chromium content had increased, while the copper content had decreased slightly. Table 4-7 shows a comparison of the metals content before and after thermal cycling. The reduction in dissolved copper content is probably due to precipitation during thermal cycling, as was observed in the compatibility and freezing point tests.

A materials balance calculation was made, based on the aged NTO, in order to determine the additional amount of iron necessary to dope the NTO in the run tank to approximately the same level as the aged propellant. Doping with nickel and chromium were not considered, based on the results from the previous study performed for JPL on possible NTO contaminants (Reference 2). The iron was added as the Addison adduct, $NO \cdot Fe(NO_3)_4 \cdot n\ N_2O_4$ which was prepared by reacting a solution of anhydrous ferric chloride in ethyl acetate with NTO, stripping off the ethyl acetate, and resuspending the reaction product in NTO.

Table 4-7. Metal Content of Nitrogen Tetroxide Used in Aging Study

Metal	Concentration, ppm Original NTO	NTO After Thermal Cycling
Iron	1.5	3.4
Copper	4.6	0.8
Nickel	0.4	1.6
Chromium	nil	0.8

Both the aged propellant and the iron dopant were added to the run tank, with filtration as done previously. Figures 4-62 and 4-63 show the material caught on the filter. Considerably more material was removed in the filter than in previous tests, as shown by a comparison of Figures 4-55 through 4-60. Additional specification grade NTO was added to the run tank to completely load the system, and the NTO was allowed to equilibrate for forty-eight hours while being heated from approximately 70°F to 90°F.

Laser scattering tests on the doped and undoped NTO are shown in Figures 4-64 and 4-65 and indicate a slightly larger Tyndall effect in the doped NTO. It could not be determined if the scattering material was suspended particulate material or colloidal in nature. Analysis of the NTO in the run tank showed a smaller iron content than calculated. Since the samples for metals analysis are filtered, as explained in Section 3.4, it is inferred that the majority of the iron in the NTO was in the form of suspended particulate matter.

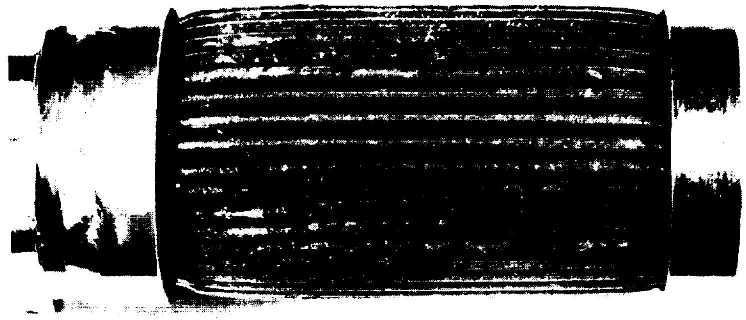


Figure 4-62. Photograph of 10μ Nominal Filter from Loading of Artificially Aged Nitrogen Tetroxide (Approximate Magnification: 2X)

Figure 4-63. Photograph of Material in Filter Housing From Loading of Artificially Aged Nitrogen Tetroxide (Approximate Magnification: 2X)

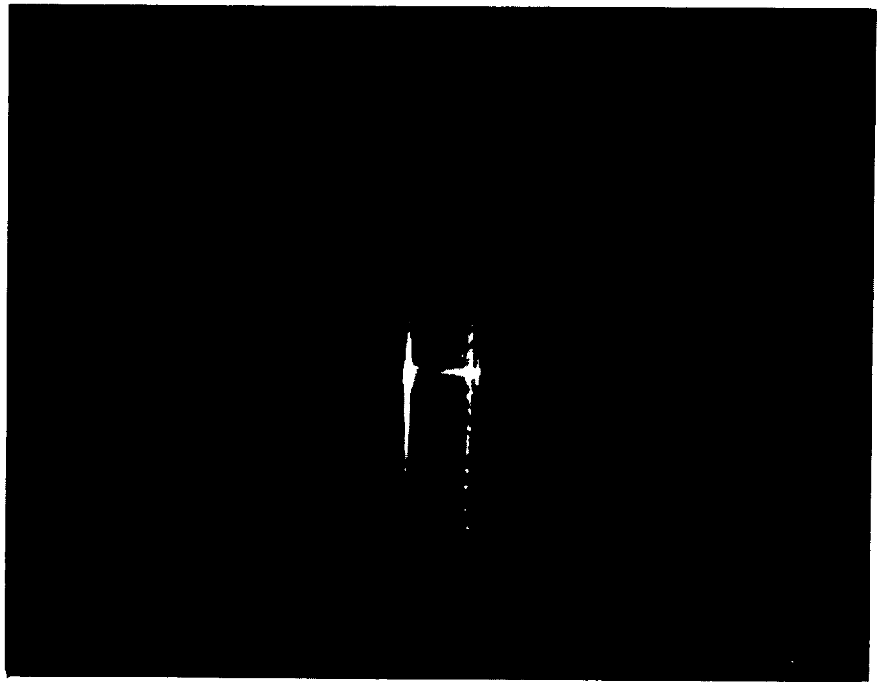


Figure 4-64. Tyndall Light Scattering Effect in Specification Grade Nitrogen Tetroxide Using He-Ne Laser

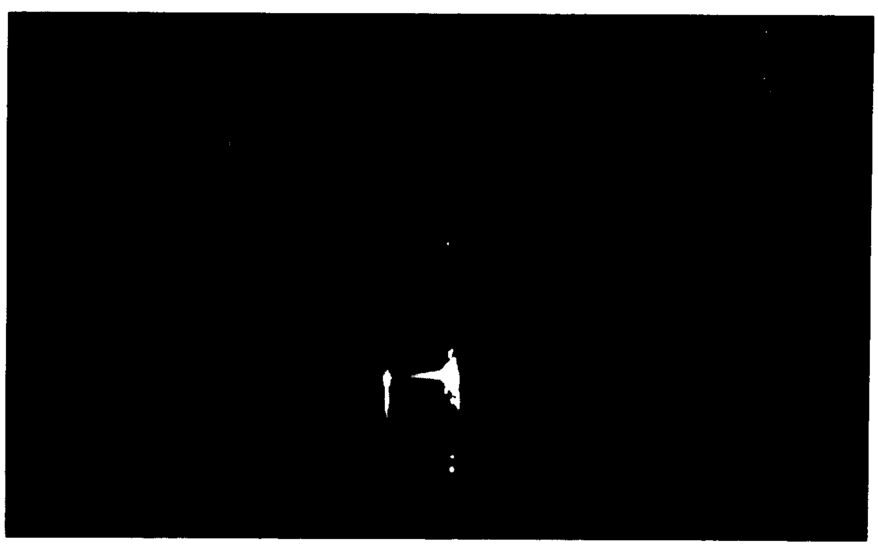


Figure 4-65. Tyndall Light Scattering Effect in Artificially Aged Nitrogen Tetroxide Using He-Ne Laser

4.4 NITROGEN TETROXIDE - BRAZE ALLOY COMPATIBILITY STUDY RESULTS

4.4.1 Nitrogen Tetroxide Analysis

The compatibility tubes were examined after termination of the thermal cycling test, and again, both white and blue-green crystalline material was noted in the bottom of the tubes. Figures 4-66 and 4-67 show the compatibility tubes, samples, and crystals. Some distortion is due to the lighting, moisture condensation, and imperfections in the glass, but the crystals are apparent in the bottom of the tubes. Because of the crystalline material, two types of analyses were performed on the NTO: analysis of the NTO fluid proper, and analysis of the crystalline material formed during the thermal cycling test. There was an insufficient amount of the blue-green crystals to be analyzed separately.

Two methods were used in an attempt to obtain the crystals for analysis: filtration through a Millipore filter, and aspiration of the NTO, leaving the crystals in the tube.

In each case, the crystals quickly deliquesced and were analyzed as a liquid. X-ray fluorescence indicated the presence of copper and iron in both samples, and in addition, nickel, manganese and chromium were found in compatibility tube No. 1. Table 4-8 gives the results of atomic absorption analyses of the material from compatibility tube No. 1.

Table 4-8. Metal Content of Crystalline Material from Compatibility Tube No. 1

Metal	Weight, μg
Copper	3.5
Nickel	5.0
Manganese	0.5
Chromium	4.0
Iron	4.0

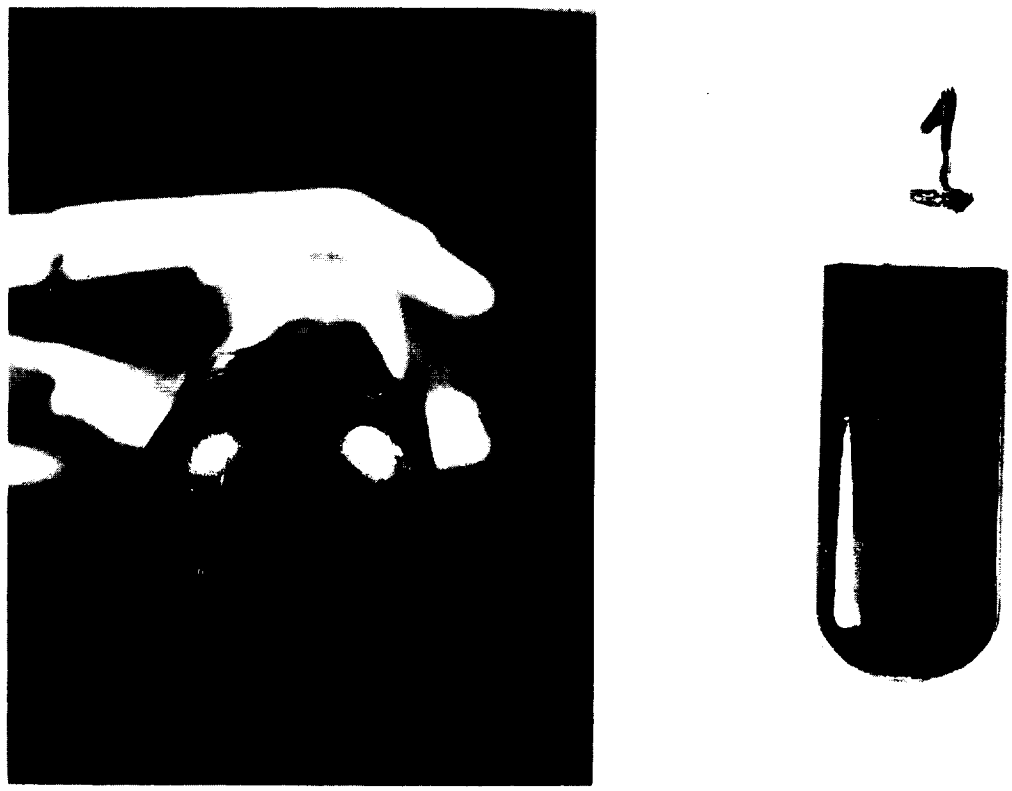


Figure 4-66. Compatibility Tubes, Samples, and Crystals

Figure 4-67. Compatibility Tubes, Samples, and Crystals

These values are relative, since the original weight of the crystals could not be determined due to the liquification. The infrared spectrum of the liquid suggested that the metals were present as nitrates, but the results are inconclusive since considerable change had occurred in the crystals upon removal from the compatibility tubes.

The NTO freed from the crystals was analyzed for dissolved metal content. The results are presented in Table 4-9 and are compared to the original NTO used in the tests.

Table 4-9. Metals Analyses of Nitrogen Tetroxide Used in NTO-Braze Alloy Compatibility Tests

	Concentration, ppm		
Metal	Original Unaged Nitrogen Tetroxide	NTO from Tube No. 1	NTO from Tube No. 2
Iron	1.4	2.9	3.5
Copper	4.7	0.7	0.9
Nickel	0.1	0.7	0.2
Manganese	nil	0.2	0.2
Chromium	nil	nil	nil

4.4.2 Braze Alloy Analysis

The original strip of braze alloy was cut into two, 1-1/2" x 1/2" test sections, with the center section reserved for metallurgical examination. The samples were degreased, ultrasonically cleaned, and then weighed, measured for thickness, and their surfaces photographed. Figures 4-68 through 4-71 show the original surface and the transverse and longitudinal cross-sections.

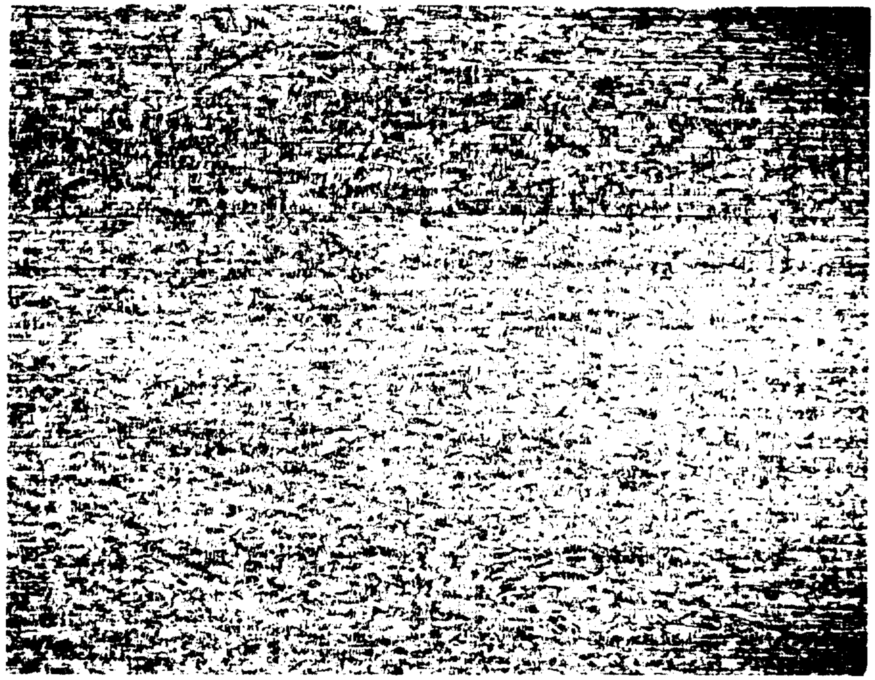


Figure 4-68. Photograph of Typical Surface of Braze Alloy Before Test (Approx. Magnification: 50X)

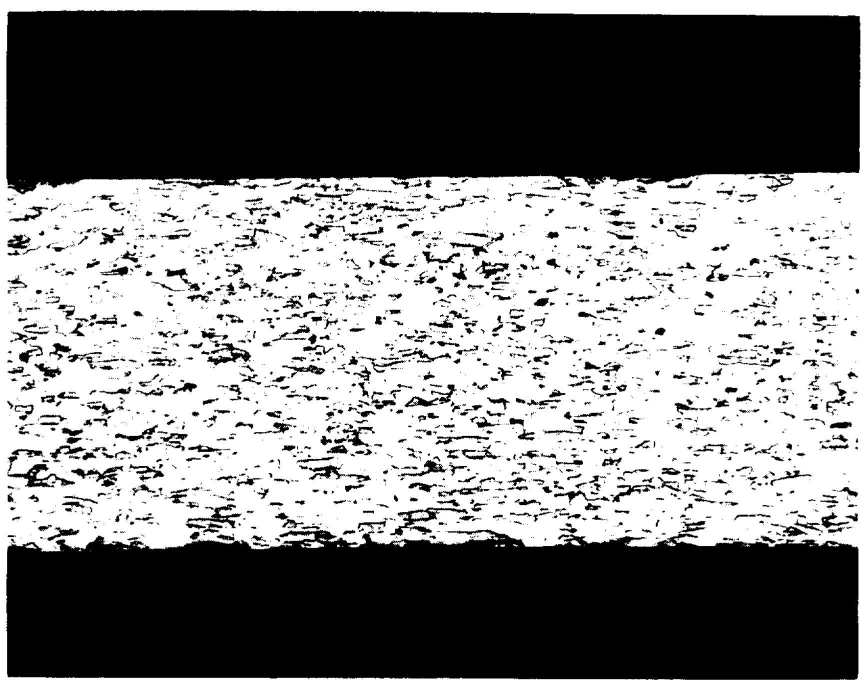


Figure 4-69. Photomicrograph of Transverse Cross-Section of Braze Alloy Before Test (Approx. Magnification: 200X)

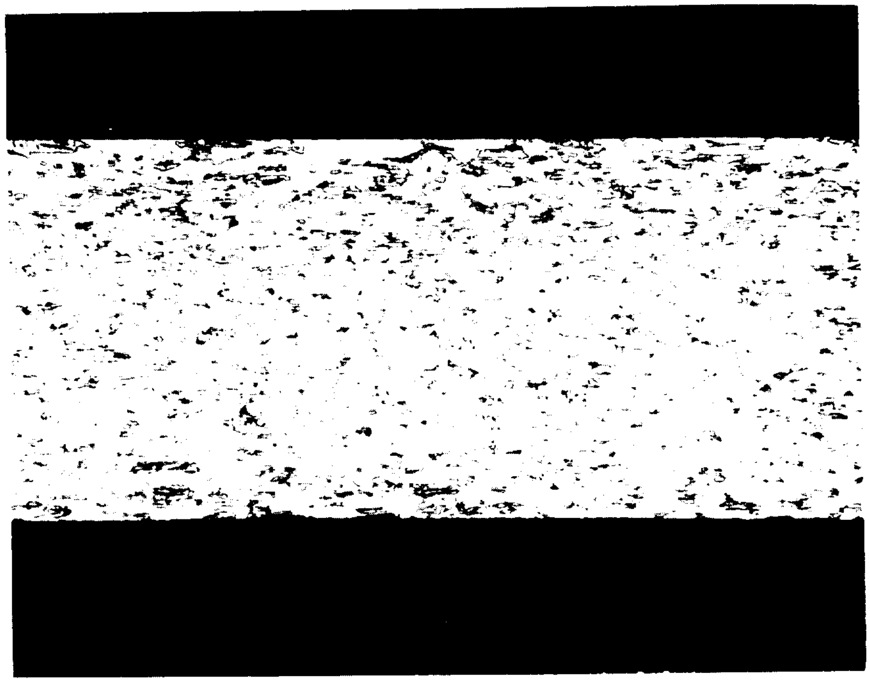


Figure 4-70. Photomicrograph of Transverse Cross-Section of Braze Alloy Before Test (Approx. Magnification: 200X)

Figure 4-71. Photomicrograph of Longitudinal Cross-Section of Braze Alloy Before Test (Approx. Magnification: 200X)

The specimens were rinsed with distilled water after removal from the compatibility tubes, and the surfaces rephotographed. Figures 4-72 through 4-74 show that the surface had picked up a deposit, but the deposit was too thin to analyze. After photographing the surfaces, the samples were cleaned as before, and weighed and measured. There was no measurable change in weight or thickness, and the cleaning had removed the previously described deposit. Microscopic examination of the surfaces showed no signs of pitting, cracking, or other corrosive attack by the NTO. The samples were then sectioned and the transverse and longitudinal cross-sections were metallurgically examined. Figures 4-75 and 4-76 show the transverse and longitudinal cross-sections after thermal cycling in NTO. No evidence of intergrannular cracking or surface attack was apparent.

The results indicate that minimal interaction had occurred between the NTO and the braze alloy over the test duration, although the presence of a surface deposit and the increase in the metals content in the NTO suggests that some reaction had taken place. This finding is corroborated by the test results from the Martin Marietta propulsion sterilization program sponsored by JPL/NASA (Reference 10), in which it was found that high nickel content alloys such as stainless steels exhibited considerable reaction with NTO at 275°F within 600 hours. This reaction generated substantial quantities of an undesirable viscous product, with the composition varying depending on the alloy tested. Such viscous products could cause clogging of filters and fine orifices.

Figure 4-72. Photograph of Braze Alloy Surface Deposits After Test in "As-Received" Condition (Approx. Magnification: 50X)

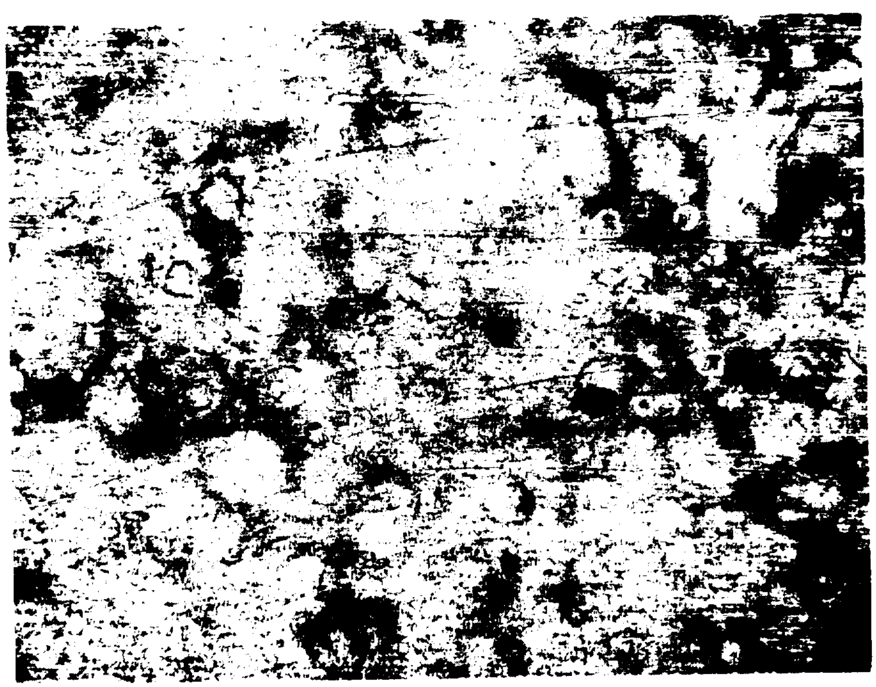


Figure 4-73. Photograph of Braze Alloy Surface Deposit After Test in "As-Received" Condition (Approx. Magnification: 50X)

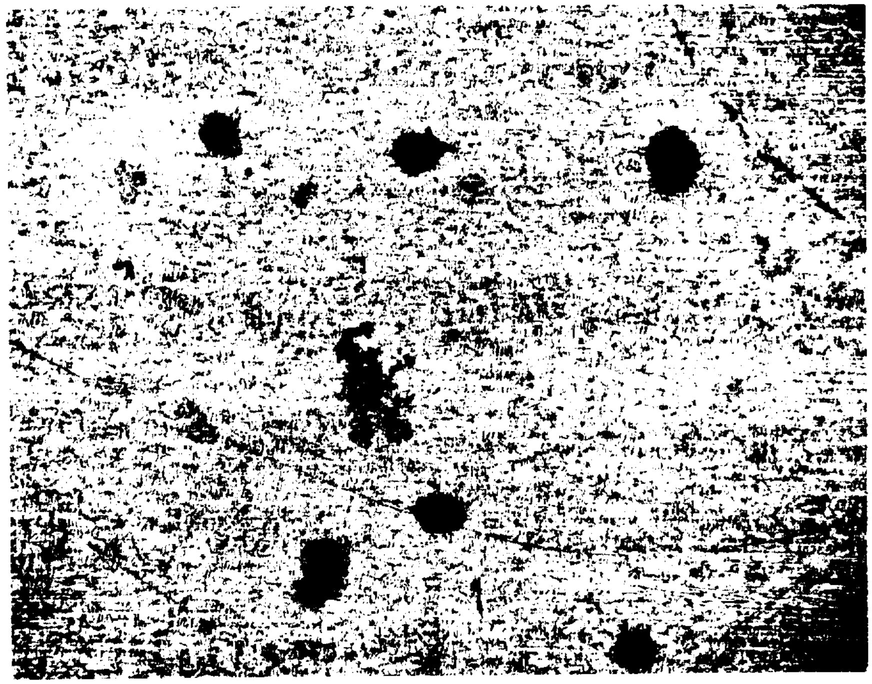


Figure 4-74. Photograph of Braze Alloy Surface Deposit After Test in "As-Received" Condition (Approx. Magnification: 50X)

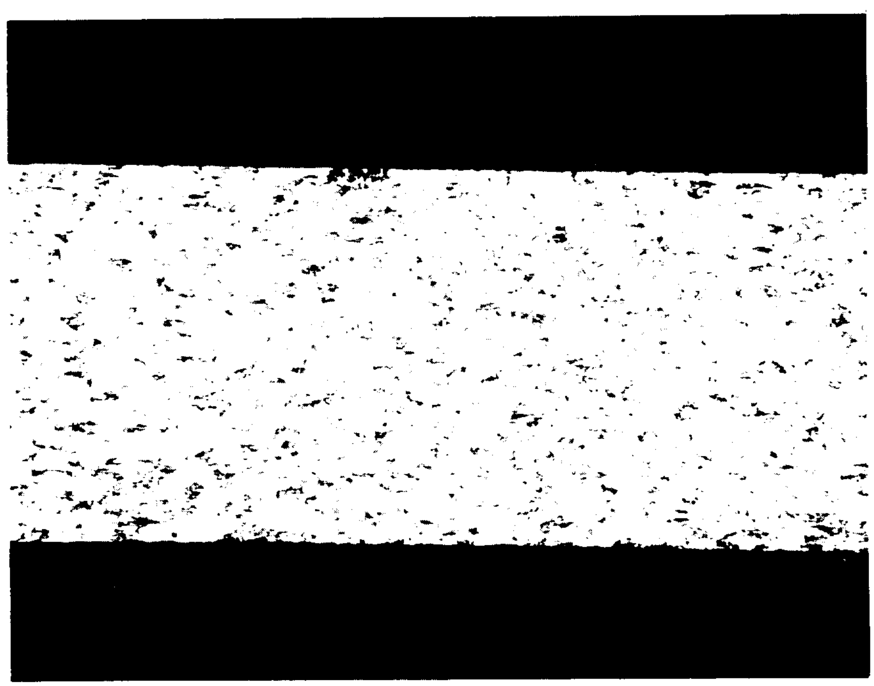


Figure 4-75. Photomicrograph of Transverse Cross-Section of Braze Alloy After Test (Approx. Magnification: 200X)

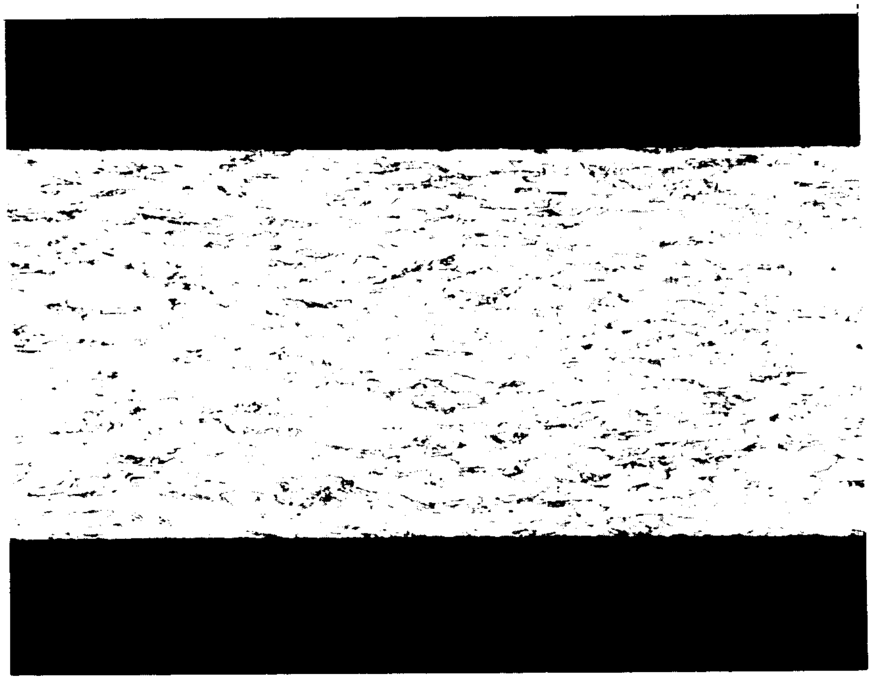


Figure 4-76. Photomicrograph of Longitudinal Cross-Section of Braze Alloy After Test (Approx. Magnification: 200X)

5.0 CONCLUSIONS

The conclusions presented are based on the testing described in Sections 3 and 4 and cannot be indiscriminately applied to other environmental conditions or other systems. These conclusions are:

1. Flow decay and other flow anomalies of up to 10 percent may be expected during flow of specification grade nitrogen tetroxide when system and propellant temperatures are between 90 and 50°F.

2. Flow anomalies and flow decays are more prevalent and more serious when operating from a hot feed tank to cold OWPS than during isothermal runs, if only flow decays exceeding two percent are considered to be significant, and the temperature range of interest is limited to between 90 to 50°F.

3. Flow anomalies and flow decays between 90 and 50°F are greater and more frequent when operating in a pulsed flow followed by steady state flow mode than when flowing in the steady state-pulsed mode.

4. Three clogging mechanisms have caused the flow anomalies and flow decays observed in this test program. These are:

   a) Formation of gels from solvated colloidal particles under flow as suggested in References 2 and 9.

   b) Generation of flow degradation products due to propellant saturation at high temperature followed by precipitation or coagulation of these products at lower temperatures.

   c) Formation of flow degradation products by crystallization or freezing at temperatures above the normal NTO freezing point.

5. The greatest flow variations encountered are in the extreme temperature test cases, namely 150°F feed tank to 150°F and 12°F OWPS and 12°F feed tank to 150°F OWPS.

6. Flow variations at the 150°F - 150°F run conditions were probably caused by generation and accumulation of contamination during feed tank warmup to 150°F. This is supported by the large initial flow fluctuations observed after flow which then slowly stabilized as the material was washed through the system.

7. Flow variations during the 150°F - 12°F run conditions are attributable to both particulate accumulation and gel formation, since both types of material were found upon system teardown and inspection.

8. Flow variations during the 12°F - 150°F run conditions are probably attributable to formation of precipitates in the feed tank at the low temperature operating condition, which reliquified as the NTO flowed through the warm OWPS. The shape of the flow curves indicate an initial decay with a gradual leveling off of flowrate and chemical tests indicate that the main precipitate liquifies below room temperature, confirming that this precipitate is the main cause of these flow anomalies. It is assumed that the 12°F - 12°F test runs did not exhibit the same magnitude of flow anomalies that the 12°F - 150°F runs did because of depletion of the precipitate from the feed tank due to the previous runs. Insufficient NTO was present in the OWPS itself to generate significant quantities of the precipitates and cause a large variation in the flowrate through the isolation valves and engines.

9. The flow tests utilizing artificially aged propellant generally behaved similarly to those using specification grade nitrogen tetroxide, except for one isothermal run at 50°F. It is assumed that particulate contamination was responsible for this flow variation.

6.0 RECOMMENDED PROBLEM SOLUTIONS

The mechanisms involved in flow decay within a system include buildup of clogging material when the NTO is subjected to high shearing velocities and/or differential temperatures, and static buildup of potential clogging material in the system from interaction between the NTO and the system. The former mechanism requires flow to occur while the latter forms statically and then physically causes flow variations or decay when the NTO is subsequently displaced by flow. A total solution should consider both of these mechanisms, therefore, a combination of "solutions" must be applied bo eliminate overall system flow problems.

Several potential solutions are outlined below:

a. Cold filtration to reduce contaminant level.

b. Use of materials of construction which do not cause a buildup of flow decay products.

c. Elimination of small orifices, clearances, and filters,

d. Tight temperature control of system and propellant.

e. Dissolution or breakup of contamination products so they will pass through orifices, clearances, and filters.

Dissolved or finely suspended contaminants can be removed to a lower contaminant level by chilling the propellant and then cold filtering with a finer mesh size filter than those used in the system. This technique should reduce the contaminant level and allow more severe operating conditions such as shearing velocities or temperature gradients than would normally cause flow variations and decay. This solution is susceptible to the resaturation reactions which occur at higher temperatures with most materials presently used in the OWPS. This saturation time varies with the material used, and the propellant.

Certain materials cause more flow degradation product buildup than others. Nickel bearing alloys such as 18-8 stainless steels produce gel-like materials when exposed to NTO at elevated temperatures. Certain aluminum and titanium alloys are the least susceptible to NTO attack (Reference 10).

The use of stainless steel alloys, particularly in the regions of high service temperatures, should be avoided.

In-system filtration should be limited to protection against the largest tolerable particle. Injector and valve orifices should be kept as large as possible, and where filters are necessary upstream of such components, the filtration area should be made as large as is possible. In the OWPS unit tested, it is recommended that the internal filters in the isolation and engine valves either be eliminated or else increased in both filter area and pore size. The two large system filters in the OWPS showed no significant signs of degrading system flow, even though their micron rating (15μ absolute) was finer than the filter strainers in the isolation and engine valves (10μ nominal - 25μ absolute).

The percent corrected flow curves presented in Section 4 show minimal flow variation during isothermal flow runs. Thus, generation and/or precipitation of flow degradation products should be minimized by tight temperature controls on the NTO supply tank and the rest of the OWPS, since flow degradation products from a saturated solution are precipitated at low temperatures and the system may resaturate itself from NTO/system materials interaction at high temperatures. It is recommended that the system be maintained at as constant a temperature as possible throughout its operating life. The use of passive thermal control techniques and coatings to accomplish this should be investigated.

Some chemical and physical techniques (References 2 and 4) have been attempted to either keep flow degradation products in solution during flow, or to remove them after formation. This work has resulted in possible short term solutions to the flow decay problem. Mechanical excitation of the flow system components is a potential method of breaking up the flow decay products and thus minimizing flow degradation. It is recommended that the use of ultrasonic excitation of the filters and/or orifices be investigated as a method of preventing the formation or accumulation of flow degradation products.

7.0 RECOMMENDED INVESTIGATIONS

The test program performed indicates that a 9 percent variation in MSC-PPD-2 NTO flow, and an 11 percent variation in artificially aged NTO flow can occur over the 90 - 50°F temperature range which encloses the expected system operational temperature spectrum. These variations were found during "cold flow" tests as described in Sections 3 and 4. It is felt that hot or simulated hot firing tests could cause a much more serious clogging problem. This is confirmed by the findings of JPL Contract 951709, Reference 10, which indicated a buildup of gel-like material on nickel bearing metal surfaces at temperatures of 275°F. Therefore, flow testing with hot firings or simulated hot firings, where actual firing temperature gradients are reproduced, is recommended for this system.

It is felt that further aging studies including the presence of all materials of system construction are warranted. This is particularly true in terms of the results of the experiments described in Reference 10. Investigations of flow with propellant artificially saturated with nickel-NTO compounds is recommended.

The blue-green crystals observed during the flow runs and temperature cycling tests of this program could cause a problem in systems exposed to temperature cycling as they form at the low temperature end of the cycle and do not redissolve at the high temperature end. This could possibly cause a gradual buildup of crystalline matter which could clog fine orifices or filters. The formation mechanics, composition, and possible elimination of these crystals require further study.

The observed white crystalline matter, which forms at approximately 1°C above the freezing point, could cause problems in systems exposed to temperatures near the freezing point of NTO. The composition and formation mechanics of these crystals should be studied further, particularly the influence of such variables as water content, NO content, dissolved metals content, and dissolved polymers and organics. It is possible that some of these could raise the freezing point further, requiring systematically higher operating temperatures.

The braze alloy corrosion studies were limited to samples of the braze alloy only. While these showed minimal braze alloy attack, the corrosion experienced in an actual brazed assembly could be significant due to the corrosion couples formed. These effects should be examined further, particularly at elevated temperatures, before brazing is used in a flight system.

The areas of recommended further investigation are:

- Hot (or simulated hot) firing flow tests
- Artificial propellant aging study with all system construction materials
- Study composition and formation mechanics of blue-green crystals
- Study composition and formation mechanics of white crystals
- Study actual braze point corrosion, and long term corrosion of other system materials in combination.

8.0 REFERENCES

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APPENDIX I

SUMMARY OF MARQUARDT MIR 272

ENGINE DESCRIPTION

The Marquardt Corporation Model R-1E-002 Rocket Engine is a hypergolic, bipropellant, pressure-fed engine nominally rated as delivering 22 pounds vacuum thrust at steady state operation. The thrustor components include solenoid valves which control the propellant flow to the single doublet injection element, injector head assembly, and a radiation cooled molybdenum thrust chamber. The solenoid valves are protected from possible contaminants by a 10 micron nominal - 25 micron absolute sediment strainer located up-stream of the valve armature. ON-OFF propellant flow is controlled by actuating either the primary coils (Coil No. 1) or the coaxial redundant coils (Coil No. 2) of the solenoid valves. The engine is orifices by restrictors in the inlet fittings to operate at a steady state mixture ratio of 1.65 using monomethylhydrazine (MMH) fuel and nitrogen tetroxide (N_2O_4) oxidizer at 70°F. It operates at a nominal chamber pressure of 95 psia.

ENGINE ENVELOPE

The critical dimensions of the Model R-1E engine are as follows:

Minimum clearance envelope diameter	=	7.040 inches
Minimum envelope length	=	10.405 inches
Nominal combustion chamber throat area	=	0.1327 inches^2
Nominal thrust chamber exit area	=	5.363 inches^2

ENGINE OPERATING REQUIREMENTS

The engine is orificed to operate at a thrust level of 22 pounds at the following propellant pressure and temperature conditions:

Nominal inlet pressure	=	213 psia
Nominal inlet temperature	=	+70 $\pm$ 10°F

Maximum operating range - The engine may be operated at any combination of the following:

Maximum inlet pressure	=	240 psia
Minimum inlet pressure	=	180 psia
Maximum inlet temperature	=	+120°F
Minimum inlet temperature	=	+20°F

The propellants may be pressurized with either helium or nitrogen gas, and may be 100% saturated with helium.

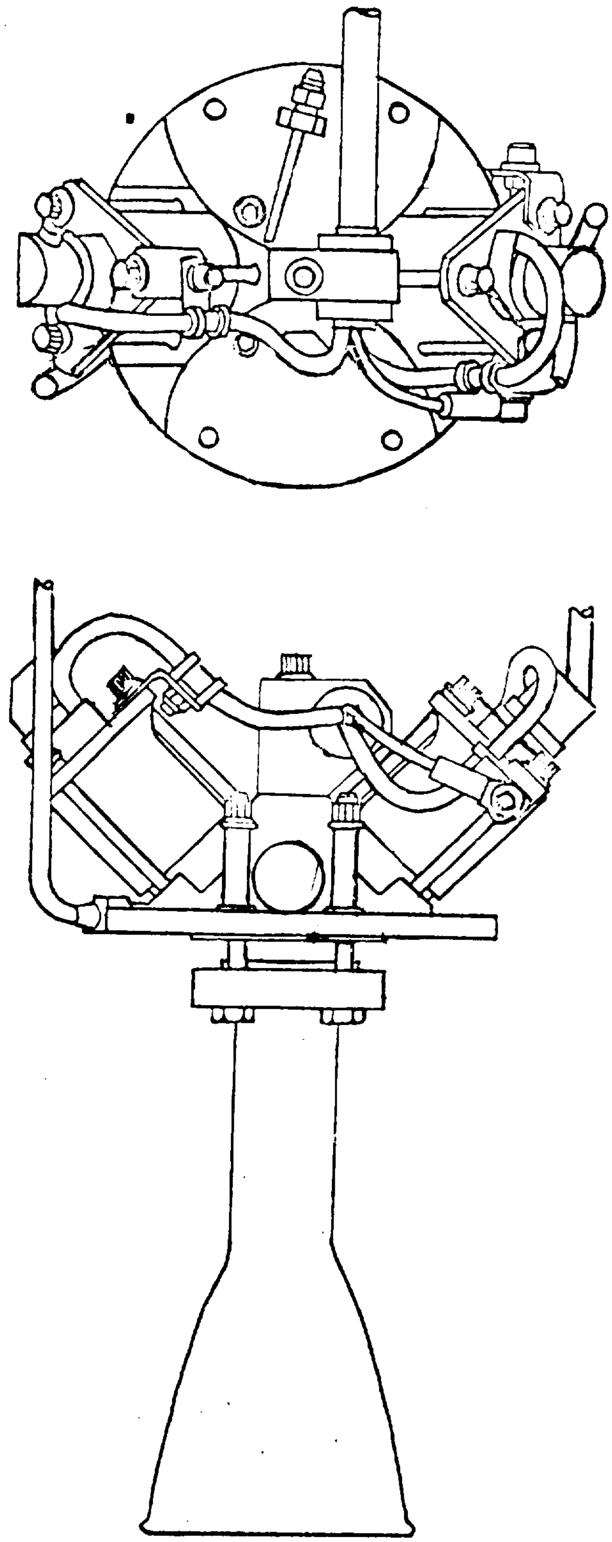
ENGINE VALVES

The valves may be actuated with a regulated d.c. voltage between 21 and 28 volts (nominal = 25 vdc). Either coil may be actuated, however, it is recommended that like coils always be used (both No. 1's or both No. 2's). The solenoid valves may be opened for any pulse width greater than 15 ms.

The propellant valves have the following nominal performance characteristics:

Opening response at 25 vdc and 203 psia inlet pressure	8 ms
Closing response at 25 mdc and rated flow	5.0 ms
Current draw at 28 vdc and 70°F	0.63 amp
Pull-in voltage at 70°F and 203 psia inlet pressure	10 vdc
Dropout current at operating conditions	0.2-0.14 amp
Dropout voltage at operating conditions	1.0-7.0 vdc
Resistance of Coil No. 1 at 75°F	43.6 ohms
Resistance of Coil No. 2 at 75°F	47.5 ohms
Maximum operating time at 28 vdc and rated flow	Unlimited

The engines as supplied for this program did not include the thrust chamber.



R-1E THRUSTOR

APPENDIX II

TEST PLAN AND PROCEDURE

NTO FLOW DECAY STUDY

CONTRACT NAS 8-21489

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1.0 OBJECTIVES

The objective of this test program is to determine if a flow decay problem exists in the Orbital Workshop Propulsion System.

2.0 BACKGROUND

Flow decay and flow stoppage have occurred in nitrogen tetroxide (NTO) flow systems containing fine filters and small clearances. This flow degradation has been investigated by TRW Systems under NASA Contracts NAS 7-107 and NAS 7-549. The clogging mechanism has been postulated to be the solvation, coagulation and final precipitation of complex iron colloids from the solution with eventual drying of the gel resulting in a crystalline powder-like residue. The phenomenon appears as an increase in NTO viscosity in high velocity flow and seems to occur in areas of turbulence and constriction such as entrances to valves, filters, orifices and capillaries. Flow blockage was observed in both capillary and filter flow tests using MSC-PPD-2A NTO as well as propellant doped with metal ions likely to be found in an aged system. The blockage was caused by a gel-like material found at the entrance to the capillary and filter which dried to a powdery crystalline residue. Changes in propellant temperature appear to be an important factor in inducing the flow decay process. The clogging material has been analyzed and found to contain iron complexes resulting from reactions between NTO, soluble impurities, and ferrous alloys used in constructing the system. Organic material has also been detected, which may synergistically contribute to the flow decay phenomenon. These analyses were performed utilizing infrared spectrometric, X-ray fluorescence and atomic absorption techniques.

3.0 SCOPE

This procedure outlines in detail, a parametric study designed to determine if a flow decay problem exists in the Orbital Workshop Propulsion Systems components supplied to TRW by the George C. Marshall Space Flight Center. Test sequence, required instrumentation, test schematics, test procedures and propellant sampling techniques are described.

4.0 COMPONENT CLEANLINESS

The NTO feed tank and any NTO wetted components in the NTO flow system upstream of the flowmeters (see Figure 1) will be cleaned to PR2-2 level 2. Gas pressurization or purge lines entering the test system or NTO feed tank upstream of the flowmeter will be cleaned to PR2-2 level 2 and a 2μ nominal 10μ absolute filter will be used at the point of attachment to the system.

5.0 PROPELLANT USED (NTO)

The NTO propellant used in the initial series of tests will meet MSC-PPD-2B when loaded into the feed tank. NTO which has been naturally or artificially aged will be used for certain critical "Doped Propellant" tests as defined in the test matrix.

6.0 OPERATING INSTRUCTIONS

These instructions are intended to describe each operating step in making the test flow runs, and include the system checkout and loading procedures to be utilized initially, or at such times that component replacement or system reclean is required.

6.1 System Checkout

Pressure check the system upstream of the engine valves with helium at 300 psi. Pressure check the catch tank and lines downstream of the engine valves with nitrogen at 200 psi. Check for leaks using "Snoop" and repair any that are found. Note: This is to be repeated whenever a component is removed or replaced.

6.2 Nitrogen Tetroxide Loading Procedure

Attach the line from the NTO cylinder to the fill and drain port on the NTO feed tank. Open the sight gauge valves and ventline on the feedback. Slowly pressurize the NTO cylinder and observe the load level on the sight gauge. A one inch differential in the sight gauge level line corresponds approximately to one gallon of NTO. Load approximately fifty (50) gallons of NTO into the feed tank, which allows for ullage and thermal expansion of the NTO during heating. Close the fill, vent, and sight gauge valves and drain sight gauge. Remove NTO cylinder and load line and attach a 500 milliliter sample bomb to the fill and drain lines. Pull a vacuum on the sample bomb and refill with dry GN_2. Open the fill and drain valve on the feed tank and open the first sample bomb valve, then the second bomb valve, and fill the bomb with NTO, allowing a small (100 ml approximately) amount of NTO to exit the bomb. Close all valves, and send sample to the Analytical Chemistry Section for analysis. If the NTO is in specification, proceed to wet the complete test section as described in Section 5.3.

6.3 Test Section Loading Procedure

Leave the hand valve and remotely actuated valve isolating the feed and catch tanks closed and evacuate the test system. Open the hand valve and remotely actuated valve isolating the feed tank from the system. Apply approximately 25 psi helium pressure to the feed tank. Open system isolation valves and engine valves and allow the NTO to flow through the system. Open the catch tank isolation valve until approximately one inch of NTO shows in the catch tank sight gauge. Close the sight gauge and isolation valves on the catch tank. The system is now ready for pressurization and temperature conditioning.

6.4 Temperature Conditioning of NTO Feed Tank and Test System

Stabilize the feed tank and test system at their required temperatures. Utilize the proportional heating or cooling rate adjustment on the controllers to avoid overheating or cold shocking the strip heaters or test components. Monitor by use of thermocouples on tank, strip heaters, and test box. This will require activating the heating and/or cooling controllers on the day before testing in order to allow stabilization of the NTO feed tank and test system. Adjust the step function heat/cool cycle with respect to the NTO tank temperature probe and test system temperature probe such that the three operating temperatures are controlled as follows:

Hot test temperature: 150°F ± 4°F

Ambient test temperature: 75°F ± 4°F

Cold test temperature: $12 {}^{+6}_{-0}$ °F

Do not allow NTO or test system to cycle below 12°F. Once the required test temperatures are stabilized, the system is ready for the test flow runs.

6.5 Test Flow Runs

6.5.1 Long Duration (600 Second) Flow Runs

After proper temperature conditioning as indicated on the Test Matrix Table 1: Open the hand operated safety valves on both the NTO feed and catch tanks. Vacate the test cell and energize the warning lights. Energize the electrically actuated feed tank valve. Pressurize the NTO feed tank to 235 ± 5 psig with gaseous helium. Use the pressure gauge for reference during pressurization, then utilize the pressure transducer for final adjustment. Pressurize the catch tank to 95 ± 5 psig with gaseous nitrogen, using the same procedure as for the feed tank. All of the differential transducers have mechanical stops allowing some temporary overpressure during this phase. Activate instrumentation, actuate dual redundant valves, and then actuate the required number of NTO engine valves (e.g., activate engine 1, or engine 2, or use special switch to activate engines 1 and 2 simultaneously) per Test Matrix and engineering direction. Allow the run to go to completion. Continuously monitor the oscillograph channels for pressures, differential pressures and flow rates. If flow or differential pressure anomalies occur, mark the strip. At the end of the run, activate snap sample bomb valve(s) while maintaining flow rate. The sample bombs are to be evacuated and back filled with clean dry nitrogen just prior to each run per 5.6.

After completion of test run series, close the helium and nitrogen pressurant lines, close the electrically activated valve at the feed tank, and vent the feed tank to the NTO vapor pressure at the holding temperature. Vent the catch tank to its ambient pressure. Turn off warning lights, enter test cell,

TABLE 1. TEST MATRIX

Run	Components	Run Duration Sec	Hold Tank Temp. °F	Component Temp. °F	Flow Rate Lb/Sec	Propellant
1	System	600	150	150	.05	Neat NTO per MSC-PPD-2A
2	System	600	150	150	.10	
3	System	600	150	75	.05	
4	System	600	150	75	.10	
5	System	600	150	12	.05	
6	System	600	150	12	.10	
7	System	600	75	150	.05	Neat NTO per MSC-PPD-2A
8	System	600	75	150	.10	
9	System	600	75	75	.05	
10	System	600	75	75	.10	
11	System	600	75	12	.05	
12	System	600	75	12	.10	
13	System	600	12	150	.05	Neat NTO per MSC-PPD-2A
14	System	600	12	150	.10	
15	System	600	12	75	.05	
16	System	600	12	75	.10	
17	System	600	12	12	.05	
18	System	600	12	12	.10	
			Worst Case (1)			
19	System	600	150	12	.10	Neat NTO per MSC-PPD-2A
20	System	600	150	12	.15	
21	System	.050 (2)	150	12	.10	
22	Worst Valve	600	150	12	.10	
23	Worst Valve	600	150	12	.15	
24	Worst Valve	.050 (2)	150	12	.10	
25	Worst Filter	600	150	12	.10	
26	Worst Filter	600	150	12	.15	
27	Worst Filter	.050 (2)	150	12	.10	
28	System	600	150	75	.05	Doped NTO
29	System	600	150	75	.10	
30	System	600	150	75	.15	
			Worst Case (1)			
31	System	600	150	12	.05	Doped NTO
32	System	600	150	12	.10	
33	System	600	150	12	.15	
34	System	.050 (2)	150	12	.10	
35	Worst Valve	600	150	12	.10	
36	Worst Valve	600	150	12	.15	
37	Worst Valve	.050 (2)	150	12	.10	
38	Worst Filter	600	150	12	.10	
39	Worst Filter	600	150	12	.15	
40	Worst Filter	.050 (2)	150	12	.10	

(1) These test conditions appeared to be worst case in the NAS 7-549 filter flow assembly study. The actual worst case conditions for this system will be determined from the test results of Runs 1 - 18.

(2) Pulsing runs will be made on a duty cycle of .060 sec on and .060 to .100 sec off for a total test duration of 60 seconds. Runs consisting of .060 sec pulses with longer hold times in between will be considered.

and close the test system/catch tank valve. Attach drain tank to catch tank and offload used NTO. Discard the NTO, and send the sample bomb(s) to the Analytical Chemistry Section for analysis.

6.5.2 Short Duration Pulse Runs

The procedure for the short duration pulse runs is identical with Section 5.5.1 with the following exception. Adjust the pulse period sequences and pulse counter to the required on/off pulse times and firing duration. Activate the sequencing switch on the firing panel. After opening the dual redundant valves, press the sequencing fire switch and allow the run to proceed. After the run is completed, activate the continuous duty engine valve switches and take NTO sample(s) as described previously.

6.6 Sample Bomb Preparation

Place the sample bombs in their respective holding clamps with the electrically actuated snap sample valve closed, open both hand valves and evacuate. Back fill with gaseous nitrogen and close the end valve, leaving the hand valve closest to the snap sample valve open. When the NTO sample is taken, the system pressure will ensure filling the bomb with the requisite amount of oxidizer.

7.0 INSTRUMENTATION

Instrumentation locations are shown on the Test Schematic, Figure 1. The data being taken includes temperatures, flows, pressures and pressure differences across all critical test system components. The transducers and recording devices used are listed in Table 2 while an estimate of overall recorded data accuracy is shown in Table 3.

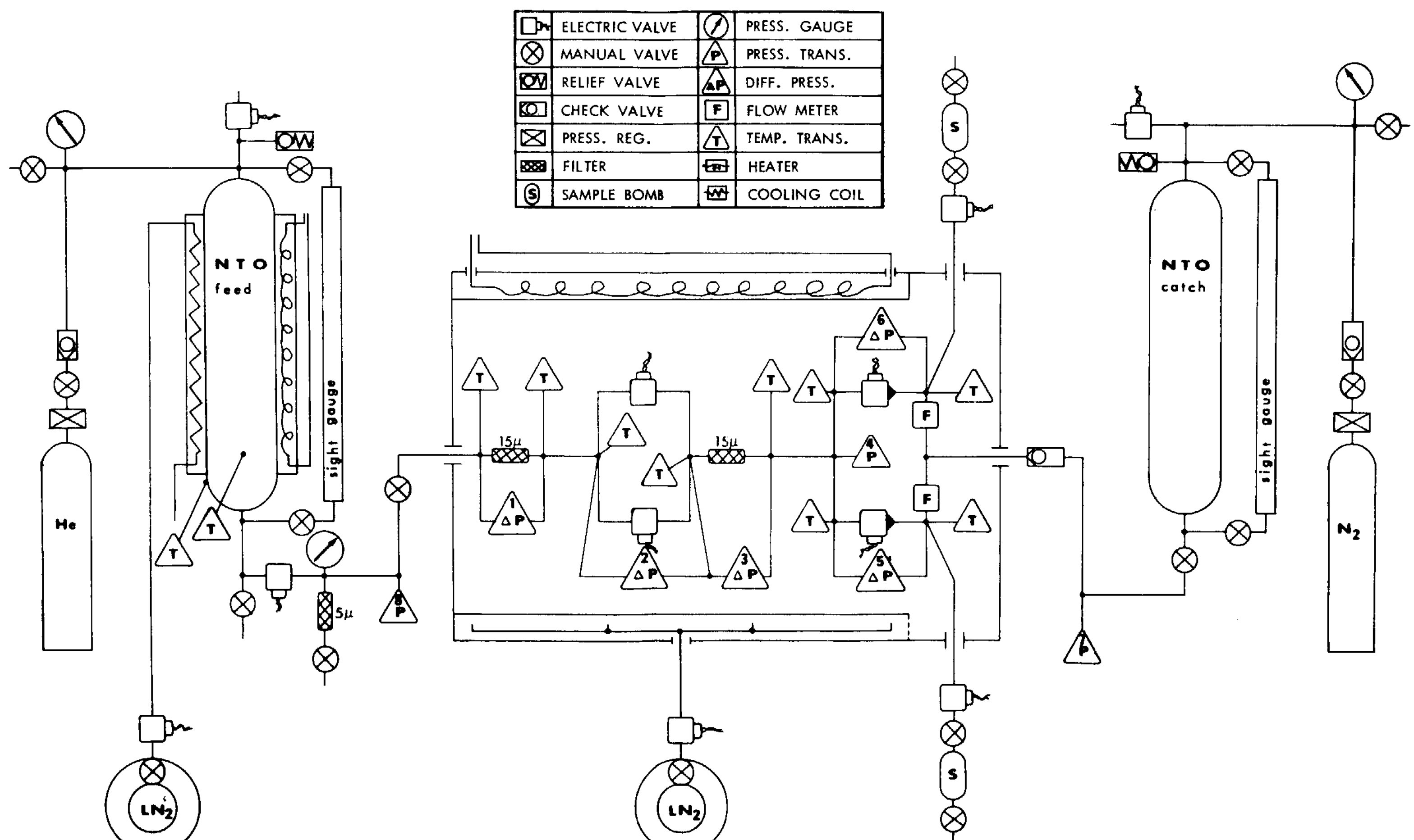


FIGURE 1. SCHEMATIC - NTO FLOW DECAY SYSTEM

Table 2. Instrumentation List

ITEM	TRANSDUCERS	
1	Data Sensors - 25 psid	S/N 101851
2	Data Sensors - 25 psid	S/N 95
3	Data Sensors - 25 psid	S/N 1140
4	Taber - 300 psig	S/N 681139
5	Data Sensors - 150 psid	S/N 459
6	Data Sensors - 150 psid	S/N 479
7	CEC - 200 psig	S/N 17025
8	Taber - 300 psig	S/N 651748
9	Right Flowmeter - Foxboro	S/N 18964
10	Left Flowmeter - Foxboro	S/N 18969
	READOUT DEVICES	
11	Visicorder - Honeywell 1508	
12	Amplifier - Honeywell 104-7	
13	Signal Conditioning Unit - Endenco 4470	
14	Pulse Rate Converter - Waugh FR-45	
15	Strip Chart Recorder - L/N W	
16	Thermocouple Reference Junction - Pace 150°	
17	EPUT and Timer - Beckman 6146	
18	Preset Unit - Beckman 622	
19	Function Generator - Exact 503	
20	Power Supply - Harrison 802B	
21	Valve Driver - TRW	
22	Multimeter - Fairchild 7050	
23	Temperature Controller - Honeywell S152R15	

Table 3. Estimated System Measurement Accuracy

Temperature

TC	± 1.5°F	
Recorder	± 0.6°F	
Ref. Junction	± 0.2°F	
	± 2.3°F	

Pressure

Transducer	± 0.25%	Linearity
Recorder	± 0.5%	
	± 0.75%	Repeatability
Rcal	± 1.0%	
	± 1.75%	Accuracy (Metrology)
Transducer Cal @ ITS	± 0.5	
	± 2.25%	

Flow

Flowmeter	± 0.2%	
Rate Convert.	± 0.2%	
Recorder	± 0.5%	
	± 0.9%	

APPENDIX III

This Appendix contains a tabular presentation of corrected flow data, in both weight and volumetric units, equivalent flow area, percent of maximum corrected flow and percent difference from maximum corrected flow. This data was used to prepare the plots of percent corrected flow and percent flow decay, presented in Section 4 of this report. It should be understood that all percentages given are based on the maximum flow experienced by that component during this test program. These maxima are identified in the tabulation and are summarized in Table 4-1.

TIME SEC.	RIGHT ENGINE ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	LEFT ENGINE ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 2										
3	.8364	36.17	63.83	.1737	.034896MIN	1.1924	13.01	86.99	.2476	.049750
10	0.0000	100.00	0.00	0.0000	0.000000	1.1778	14.07	85.93	.2446	.049142
15	0.0000	100.00	0.00	0.0000	0.000000	1.1345	17.23	82.77	.2356	.047336
20	0.0000	100.00	0.00	0.0000	0.000000	1.2024	12.28	87.72	.2497	.050168
30	0.0000	100.00	0.00	0.0000	0.000000	1.2073	11.92	88.08	.2507	.050370
45	0.0000	100.00	0.00	0.0000	0.000000	1.1378	16.99	83.01	.2363	.047470
60	0.0000	100.00	0.00	0.0000	0.000000	1.1411	16.75	83.25	.2370	.047608
120	0.0000	100.00	0.00	0.0000	0.000000	1.1483	16.22	83.78	.2385	.047910
180	0.0000	100.00	0.00	0.0000	0.000000	1.1768	14.15	85.85	.2444	.049098
240	0.0000	100.00	0.00	0.0000	0.000000	1.2055	12.05	87.95	.2503	.050295
300	0.0000	100.00	0.00	0.0000	0.000000	1.2457	9.12	90.88	.2587	.051974
360	0.0000	100.00	0.00	0.0000	0.000000	1.2480	8.95	91.05	.2592	.052069
635	0.0000	100.00	0.00	0.0000	0.000000	1.2583	8.20	91.80	.2613	.052501
705	.9769	25.45	74.55	.2029	.040757	1.2228	10.79	89.21	.2539	.051017
942	.9645	26.39	73.61	.2003	.040242	1.2252	10.62	89.38	.2544	.051118
1275	1.0272	21.61	78.39	.2133	.042855	1.2746	7.01	92.99	.2647	.053180
RUN 3										
5	0.0000	100.00	0.00	0.0000	0.000000	1.1804	13.89	86.11	.2451	.049247
45	0.0000	100.00	0.00	0.0000	0.000000	1.1749	14.29	85.71	.2440	.049018
67	0.0000	100.00	0.00	0.0000	0.000000	1.2711	7.26	92.74	.2640	.053034
225	0.0000	100.00	0.00	0.0000	0.000000	1.2068	11.96	88.04	.2506	.050349
605	0.0000	100.00	0.00	0.0000	0.000000	1.1853	13.53	86.47	.2461	.049451
635	1.0461	20.17	79.83	.2172	.043646	1.1856	13.50	86.50	.2462	.049467
775	1.0373	20.84	79.16	.2154	.043277	1.2099	11.73	88.27	.2513	.050481
1105	1.0301	21.39	78.61	.2139	.042977	1.1812	13.83	86.17	.2453	.049281

TIME SEC.	RIGHT ENGINE ACTUAL AREA SQ.IN. X1000	RIGHT ENGINE DIFF FROM MAXIMUM PERCENT	RIGHT ENGINE PERCENT OF MAXIMUM PERCENT	RIGHT ENGINE CORRECTED FLOW GPM	RIGHT ENGINE CORRECTED FLOW PPS	LEFT ENGINE ACTUAL AREA SQ.IN. X1000	LEFT ENGINE DIFF FROM MAXIMUM PERCENT	LEFT ENGINE PERCENT OF MAXIMUM PERCENT	LEFT ENGINE CORRECTED FLOW GPM	LEFT ENGINE CORRECTED FLOW PPS
RUN 4										
40	0.0000	100.00	0.00	0.0000	0.000000	1.2374	9.72	90.28	.2570	.051628
75	0.0000	100.00	0.00	0.0000	0.000000	1.2278	10.43	89.57	.2550	.051224
120	0.0000	100.00	0.00	0.0000	0.000000	1.2356	9.85	90.15	.2566	.051554
180	0.0000	100.00	0.00	0.0000	0.000000	1.1875	13.36	86.64	.2466	.049546
240	0.0000	100.00	0.00	0.0000	0.000000	1.1670	14.86	85.14	.2423	.048688
300	0.0000	100.00	0.00	0.0000	0.000000	1.1673	14.84	85.16	.2424	.048703
360	0.0000	100.00	0.00	0.0000	0.000000	1.1573	15.57	84.43	.2403	.048284
420	0.0000	100.00	0.00	0.0000	0.000000	1.1645	15.04	84.96	.2418	.048586
480	0.0000	100.00	0.00	0.0000	0.000000	1.1577	15.54	84.46	.2404	.048303
540	0.0000	100.00	0.00	0.0000	0.000000	1.1660	14.93	85.07	.2421	.048650
600	0.0000	100.00	0.00	0.0000	0.000000	1.1724	14.47	85.53	.2435	.048916
RUN 5										
15	0.0000	100.00	0.00	0.0000	0.000000	1.2197	11.02	88.98	.2533	.050887
19	0.0000	100.00	0.00	0.0000	0.000000	1.1922	13.02	86.98	.2476	.049740
30	0.0000	100.00	0.00	0.0000	0.000000	1.1946	12.85	87.15	.2481	.049840
55	0.0000	100.00	0.00	0.0000	0.000000	1.3372	2.44	97.56	.2777	.055792
190	0.0000	100.00	0.00	0.0000	0.000000	1.2506	8.76	91.24	.2597	.052177
270	0.0000	100.00	0.00	0.0000	0.000000	1.2169	11.22	88.78	.2527	.050773
460	0.0000	100.00	0.00	0.0000	0.000000	1.1904	13.15	86.85	.2472	.049666
600	0.0000	100.00	0.00	0.0000	0.000000	1.1823	13.74	86.26	.2455	.049329
RUN 6										
8	1.0416	20.51	79.49	.2163	.043457	0.0000	100.00	0.00	0.0000	0.000000
28	1.0475	20.06	79.94	.2175	.043703	0.0000	100.00	0.00	0.0000	0.000000
120	1.0562	19.40	80.60	.2193	.044066	0.0000	100.00	0.00	0.0000	0.000000
360	1.0257	21.72	78.28	.2130	.042795	0.0000	100.00	0.00	0.0000	0.000000
600	1.0096	22.95	77.05	.2097	.042122	0.0000	100.00	0.00	0.0000	0.000000

TIME SEC.	RIGHT ENGINE ACTUAL AREA SQ.IN. X1000	RIGHT ENGINE DIFF FROM MAXIMUM PERCENT	RIGHT ENGINE PERCENT OF MAXIMUM PERCENT	RIGHT ENGINE CORRECTED GPM	RIGHT ENGINE FLOW PPS	LEFT ENGINE ACTUAL AREA SQ.IN. X1000	LEFT ENGINE DIFF FROM MAXIMUM PERCENT	LEFT ENGINE PERCENT OF MAXIMUM PERCENT	LEFT ENGINE CORRECTED GPM	LEFT ENGINE FLOW PPS
RUN 7										
-1	0.0000	100.00	0.00	0.0000	0.000000	0.0000	100.00	0.00	0.0000	0.000000
0	.9429	28.05	71.95	.1958	.039338	1.1555	15.70	84.30	.2400	.048211
4	.9912	24.36	75.64	.2058	.041356	1.2102	11.71	88.29	.2513	.050493
7	1.0780	17.73	82.27	.2239	.044977	1.1883	13.31	86.69	.2468	.049578
10	1.0810	17.51	82.49	.2245	.045100	1.1846	13.58	86.42	.2460	.049423
13	1.0843	17.25	82.75	.2252	.045240	1.1839	13.63	86.37	.2458	.049395
18	1.0881	16.96	83.04	.2260	.045397	1.1838	13.64	86.36	.2458	.049389
22	1.0912	16.73	83.27	.2266	.045525	1.1835	13.66	86.34	.2458	.049379
27	1.1068	15.54	84.46	.2298	.046178	1.1903	13.16	86.84	.2472	.049660
34	1.1108	15.23	84.77	.2307	.046345	1.2973	5.35	94.65	.2694	.054127
39	1.1184	14.65	85.35	.2322	.046661	1.3606	.74	99.26	.2825	.056765
56	1.1078	15.46	84.54	.2300	.046219	1.3092	4.48	95.52	.2719	.054625
72	1.0976	16.24	83.76	.2279	.045793	1.2773	6.81	93.19	.2652	.053292
110	1.0773	17.79	82.21	.2237	.044948	1.2225	10.81	89.19	.2539	.051004
142	1.0661	18.64	81.36	.2214	.044481	1.1947	12.84	87.16	.2481	.049844
201	1.0457	20.20	79.80	.2171	.043627	1.1716	14.52	85.48	.2433	.048883
289	1.0409	20.56	79.44	.2162	.043430	1.1597	15.40	84.60	.2408	.048384
348	1.0444	20.30	79.70	.2169	.043576	1.1565	15.63	84.37	.2402	.048250
407	1.0508	19.81	80.19	.2182	.043842	1.1528	15.90	84.10	.2394	.048097
600	1.0448	20.27	79.73	.2170	.043590	1.1445	16.50	83.50	.2377	.047753
RUN 8										
5	1.2291	6.20	93.80	.2552	.051282	1.2149	11.37	88.63	.2523	.050687
20	1.2266	6.39	93.61	.2547	.051176	1.2095	11.76	88.24	.2512	.050462
40	1.2268	6.38	93.62	.2548	.051185	1.2107	11.67	88.33	.2514	.050514
60	1.2231	6.66	93.34	.2540	.051031	1.2106	11.68	88.32	.2514	.050508
80	1.2198	6.91	93.09	.2533	.050893	1.2129	11.51	88.49	.2519	.050604
100	1.2224	6.72	93.28	.2538	.051000	1.2137	11.46	88.54	.2520	.050637

TIME SEC.	RIGHT ENGINE ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	LEFT ENGINE ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 9										
3	1.2504	4.58	95.42	.2597	.052170	1.2400	9.53	90.47	.2575	.051737
60	1.2372	5.59	94.41	.2569	.051617	1.2435	9.28	90.72	.2582	.051882
120	1.2304	6.10	93.90	.2555	.051336	1.2404	9.51	90.49	.2576	.051751
180	1.2270	6.36	93.64	.2548	.051195	1.2385	9.64	90.36	.2572	.051674
500	1.2332	5.89	94.11	.2561	.051450	1.2405	9.50	90.50	.2576	.051755
560	1.2332	5.89	94.11	.2561	.051453	1.2386	9.64	90.36	.2572	.051676
620	1.2328	5.92	94.08	.2560	.051435	1.2389	9.62	90.38	.2573	.051689
RUN 10										
350	1.2034	8.17	91.83	.2499	.050207	1.1984	12.57	87.43	.2489	.050002
420	1.2048	8.06	91.94	.2502	.050265	1.2010	12.38	87.62	.2494	.050108
470	1.2029	8.20	91.80	.2498	.050188	1.1991	12.52	87.48	.2490	.050030
RUN 12										
3	1.2368	5.61	94.39	.2568	.051604	1.2295	10.30	89.70	.2553	.051297
13	1.2357	5.70	94.30	.2566	.051557	1.2270	10.48	89.52	.2548	.051193
30	1.2376	5.55	94.45	.2570	.051636	1.2278	10.43	89.57	.2550	.051226
60	1.2473	4.82	95.18	.2590	.052038	1.2338	9.98	90.02	.2562	.051479
120	1.2505	4.57	95.43	.2597	.052172	1.2380	9.68	90.32	.2571	.051652
180	1.2407	5.32	94.68	.2577	.051766	1.2322	10.11	89.89	.2559	.051409
RUN 13										
260	1.2258	6.46	93.54	.2545	.051142	1.2235	10.74	89.26	.2541	.051046
320	1.2368	5.61	94.39	.2568	.051603	1.2327	10.07	89.93	.2560	.051432
400	1.2285	6.25	93.75	.2551	.051255	1.2252	10.61	89.39	.2544	.051118
500	1.2188	6.99	93.01	.2531	.050849	1.2201	10.99	89.01	.2534	.050906

TIME	RIGHT ENGINE					LEFT ENGINE				
	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
SEC.										
RUN 14										
4	1.2318	6.00	94.00	.2558	.051394	1.2266	10.51	89.49	.2547	.051176
20	1.2339	5.84	94.16	.2562	.051482	1.2208	10.93	89.07	.2535	.050935
30	1.2308	6.07	93.93	.2556	.051353	1.2225	10.82	89.18	.2539	.051003
50	1.2416	5.25	94.75	.2578	.051803	1.2295	10.31	89.69	.2553	.051295
60	1.2542	4.29	95.71	.2604	.052328	1.2336	10.00	90.00	.2562	.051467
120	1.2376	5.56	94.44	.2570	.051634	1.2206	10.95	89.05	.2535	.050925
180	1.2257	6.46	93.54	.2545	.051141	1.2117	11.60	88.40	.2516	.050556
240	1.2228	6.68	93.32	.2539	.051018	1.2117	11.60	88.40	.2516	.050555
300	1.2185	7.01	92.99	.2530	.050839	1.2070	11.94	88.06	.2506	.050358
RUN 15										
120	1.2024	8.24	91.76	.2497	.050165	1.2383	9.66	90.34	.2572	.051666
180	1.2087	7.76	92.24	.2510	.050431	1.2183	11.12	88.88	.2530	.050831
250	1.2126	7.46	92.54	.2518	.050593	1.2160	11.29	88.71	.2525	.050733
400	1.2208	6.84	93.16	.2535	.050934	1.2063	12.00	88.00	.2505	.050328
RUN 16										
115	1.2433	5.12	94.88	.2582	.051871	1.3061	4.72	95.28	.2712	.054491
171	1.2096	7.69	92.31	.2512	.050467	1.2963	5.43	94.57	.2692	.054084
226	1.1827	9.74	90.26	.2456	.049347	1.2722	7.19	92.81	.2642	.053077
RUN 17										
10	1.2241	6.58	93.42	.2542	.051073	1.3073	4.63	95.37	.2715	.054542
23	1.1796	9.98	90.02	.2450	.049215	1.2691	7.41	92.59	.2635	.052948
40	1.1515	12.12	87.88	.2391	.048045	1.1542	15.80	84.20	.2397	.048154
80	1.1571	11.70	88.30	.2403	.048278	1.1596	15.40	84.60	.2408	.048382
150	1.1731	10.48	89.52	.2436	.048944	1.1724	14.46	85.54	.2435	.048917
300	1.1793	10.01	89.99	.2449	.049202	1.1768	14.14	85.86	.2444	.049100

	RIGHT ENGINE					LEFT ENGINE				
TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 18										
56	1.2151	7.27	92.73	.2523	.050695	1.2537	8.54	91.46	.2603	.052305
120	1.2056	8.00	92.00	.2504	.050300	1.2484	8.92	91.08	.2592	.052086
182	1.2046	8.07	91.93	.2501	.050259	1.2475	8.99	91.01	.2591	.052050
245	1.2029	8.20	91.80	.2498	.050186	1.2528	8.60	91.40	.2602	.052269
300	1.2362	5.66	94.34	.2567	.051575	1.2580	8.22	91.78	.2612	.052488
400	1.2174	7.10	92.90	.2528	.050791	1.2633	7.84	92.16	.2623	.052707
480	1.2106	7.61	92.39	.2514	.050511	1.2638	7.80	92.20	.2624	.052727
550	1.2071	7.88	92.12	.2507	.050364	1.2647	7.74	92.26	.2626	.052764
570	1.2102	7.64	92.36	.2513	.050494	1.2572	8.28	91.72	.2611	.052451
RUN 19										
10	1.3027	.59	99.41	.2705	.054352	1.2261	10.55	89.45	.2546	.051154
70	1.3094	.08	99.92	.2719	.054629	1.2268	10.50	89.50	.2547	.051183
240	1.3104	.00	100.00	.2721	.054672MAX	1.2318	10.13	89.87	.2558	.051395
270	1.2987	.89	99.11	.2697	.054183	1.2318	10.13	89.87	.2558	.051395
420	1.2804	2.29	97.71	.2659	.053422	1.2232	10.76	89.24	.2540	.051036
496	1.2684	3.20	96.80	.2634	.052921	1.2318	10.13	89.87	.2558	.051395
560	1.2651	3.46	96.54	.2627	.052783	1.2323	10.10	89.90	.2559	.051413
610	1.2714	2.98	97.02	.2640	.053045	1.2253	10.61	89.39	.2544	.051122
RUN 20										
60	1.1460	12.55	87.45	.2380	.047813	1.2410	9.46	90.54	.2577	.051778
120	1.1546	11.89	88.11	.2398	.048173	1.2483	8.93	91.07	.2592	.052082
380	1.1660	11.02	88.98	.2421	.048646	1.2516	8.69	91.31	.2599	.052219
240	1.1702	10.69	89.31	.2430	.048825	1.2450	9.17	90.83	.2585	.051946
300	1.1690	10.79	89.21	.2428	.048773	1.2315	10.16	89.84	.2557	.051381
360	1.1808	9.89	90.11	.2452	.049267	1.2256	10.59	89.41	.2545	.051134

	RIGHT ENGINE					LEFT ENGINE				
TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 21										
3	1.1676	10.90	89.10	.2425	.048715	1.2240	10.71	89.29	.2542	.051066
60	1.1694	10.76	89.24	.2428	.048792	1.2308	10.21	89.79	.2556	.051351
120	1.1640	11.17	88.83	.2417	.048564	1.2322	10.10	89.90	.2559	.051412
180	1.1640	11.17	88.83	.2417	.048564	1.2322	10.10	89.90	.2559	.051412
240	1.1951	8.80	91.20	.2482	.049861	1.2354	9.87	90.13	.2565	.051545
300	1.1794	9.99	90.01	.2449	.049208	1.2354	9.87	90.13	.2565	.051545
360	1.1902	9.17	90.83	.2472	.049660	1.2347	9.93	90.07	.2564	.051513
RUN 22										
2	1.2152	7.27	92.73	.2523	.050699	1.2462	9.08	90.92	.2588	.051995
60	1.2086	7.77	92.23	.2510	.050427	1.2379	9.69	90.31	.2571	.051647
120	1.2053	8.02	91.98	.2503	.050288	1.2321	10.11	89.89	.2559	.051406
180	1.2022	8.26	91.74	.2496	.050157	1.2326	10.08	89.92	.2560	.051426
240	1.2070	7.89	92.11	.2507	.050360	1.2228	10.79	89.21	.2539	.051016
300	1.2026	8.23	91.77	.2497	.050173	1.2301	10.26	89.74	.2554	.051323
360	1.2049	8.05	91.95	.2502	.050272	1.2304	10.23	89.77	.2555	.051336
RUN 23										
5	1.2062	7.95	92.05	.2505	.050324	1.2315	10.15	89.85	.2557	.051383
60	1.1980	8.58	91.42	.2488	.049984	1.2314	10.16	89.84	.2557	.051377
120	1.2003	8.40	91.60	.2493	.050079	1.2317	10.14	89.86	.2558	.051388
180	1.2022	8.26	91.74	.2496	.050158	1.2308	10.21	89.79	.2556	.051350
240	1.1988	8.52	91.48	.2489	.050015	1.2268	10.50	89.50	.2547	.051183
300	1.1927	8.98	91.02	.2477	.049764	1.2238	10.71	89.29	.2541	.051061
360	1.1927	8.98	91.02	.2477	.049764	1.2238	10.71	89.29	.2541	.051061

I S O L A T I O N   V A L V E

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
R U N 21	LEFT VALVE				
3	9.222	8.54	91.46	.4945	.099344
60	9.171	9.05	90.95	.4917	.098791
120	9.254	8.23	91.77	.4962	.099689
180	9.237	8.40	91.60	.4953	.099504
240	9.349	7.28	92.72	.5013	.100713
300	9.119	9.56	90.44	.4889	.098236
360	9.248	8.28	91.72	.4959	.099628
R U N 22	RIGHT VALVE				
2	9.799	7.43	92.57	.5254	.105565
60	9.872	6.74	93.26	.5293	.106349
120	9.819	7.24	92.76	.5265	.105781
180	9.769	7.71	92.29	.5238	.105239
240	9.682	8.53	91.47	.5191	.104304
300	9.840	7.04	92.96	.5276	.106005
360	9.829	7.15	92.85	.5270	.105880
R U N 23	LEFT VALVE				
5	9.392	6.86	93.14	.5036	.101173
60	9.465	6.14	93.86	.5075	.101959
120	9.472	6.07	93.93	.5078	.102035
180	9.479	6.00	94.00	.5082	.102112
240	9.468	6.11	93.89	.5076	.101992
300	9.407	6.71	93.29	.5044	.101335
360	9.389	6.89	93.11	.5034	.101144

I S O L A T I O N   V A L V E

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
R U N 24	RIGHT VALVE				
1	10.049	5.07	94.93	.5388	.108250
2	9.896	6.51	93.49	.5306	.106610
60	9.904	6.44	93.56	.5310	.106695
61	9.872	6.74	93.26	.5293	.106345
62	9.803	7.39	92.61	.5256	.105609
120	9.788	7.53	92.47	.5248	.105444
180	9.803	7.39	92.61	.5256	.105609
240	9.890	6.57	93.43	.5303	.106541
300	9.890	6.57	93.43	.5303	.106541
360	9.833	7.11	92.89	.5272	.105924
R U N 25	LEFT VALVE				
1	9.716	3.64	96.36	.5209	.104666
60	9.678	4.02	95.98	.5189	.104254
120	9.660	4.19	95.81	.5180	.104068
180	9.630	4.49	95.51	.5163	.103742
240	9.502	5.77	94.23	.5095	.102360
300	9.510	5.69	94.31	.5099	.102444
360	9.511	5.67	94.33	.5100	.102462
R U N 26	RIGHT VALVE				
1	9.939	6.11	93.89	.5329	.107071
4	9.833	7.11	92.89	.5272	.105922
15	9.936	6.14	93.86	.5327	.107037
60	9.870	6.76	93.24	.5292	.106326
120	9.873	6.74	93.26	.5293	.106353
200	9.908	6.40	93.60	.5312	.106735
260	9.939	6.11	93.89	.5329	.107067
300	9.912	6.36	93.64	.5315	.106783

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 27	LEFT VALVE				
1	9.575	5.04	94.96	.5134	.103152
60	9.540	5.39	94.61	.5115	.102773
120	9.493	5.86	94.14	.5090	.102264
180	9.432	6.46	93.54	.5057	.101608
240	9.516	5.63	94.37	.5102	.102513
300	9.535	5.44	94.56	.5112	.102714
360	9.496	5.82	94.18	.5092	.102301
RUN 28	BOTH VALVES				
2	17.731	10.23	89.77	.4753	.095504
25	17.840	9.68	90.32	.4783	.096093
29	16.509	16.42	83.58	.4426	.088921
54	16.509	16.42	83.58	.4426	.088921
57	16.632	15.79	84.21	.4459	.089587
81	16.516	16.38	83.62	.4428	.088961
RUN 29	LEFT VALVE				
3	9.138	9.38	90.62	.4899	.098438
60	9.317	7.60	92.40	.4995	.100364
120	9.294	7.83	92.17	.4983	.100115
183	9.328	7.49	92.51	.5001	.100488
186	9.538	5.41	94.59	.5114	.102744
189	9.383	6.94	93.06	.5031	.101082
240	9.406	6.71	93.29	.5044	.101332
300	9.187	8.89	91.11	.4926	.098968
360	9.181	8.95	91.05	.4923	.098905

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 30	RIGHT VALVE				
3	9.660	8.74	91.26	.5180	.104066
20	9.606	9.25	90.75	.5151	.103486
33	9.968	5.83	94.17	.5345	.107383
36	10.151	4.11	95.89	.5443	.109350
55	10.157	4.05	95.95	.5446	.109412
120	10.003	5.50	94.50	.5363	.107759
180	10.024	5.30	94.70	.5375	.107990
240	10.069	4.88	95.12	.5399	.108471
300	10.046	5.10	94.90	.5387	.108224
360	10.194	3.70	96.30	.5466	.109812
RUN 31	LEFT VALVE				
3	9.703	3.77	96.23	.5202	.104525
60	9.762	3.19	96.81	.5234	.105159
120	9.667	4.13	95.87	.5183	.104138
180	9.823	2.58	97.42	.5267	.105823
250	9.332	7.45	92.55	.5004	.100529
300	9.107	9.68	90.32	.4883	.098109
350	8.963	11.11	88.89	.4806	.096554
360	9.036	10.39	89.61	.4845	.097343
RUN 32	RIGHT VALVE				
3	10.289	2.80	97.20	.5517	.110839
17	10.272	2.96	97.04	.5508	.110661
19	10.191	3.73	96.27	.5464	.109783
23	10.367	2.07	97.93	.5558	.111677
33	10.499	.81	99.19	.5629	.113105
50	10.586	.00	100.00	.5676	.114034MAX
110	10.380	1.94	98.06	.5565	.111818
180	10.237	3.29	96.71	.5489	.110280

ISOLATION VALVE

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 32	RIGHT VALVE		CONTINUED		
240	10.322	2.49	97.51	.5535	.111199
300	10.337	2.35	97.65	.5542	.111357
360	10.250	3.17	96.83	.5496	.110416
362	10.405	1.71	98.29	.5579	.112085
RUN 33	LEFT VALVE				
3	8.879	11.94	88.06	.4761	.095652
10	8.882	11.91	88.09	.4762	.095685
60	8.915	11.59	88.41	.4780	.096033
120	8.872	12.01	87.99	.4757	.095580
180	8.898	11.75	88.25	.4771	.095857
240	8.876	11.97	88.03	.4759	.095623
300	8.930	11.44	88.56	.4788	.096199
360	8.856	12.17	87.83	.4748	.095401
RUN 34	RIGHT VALVE				
3	9.603	9.28	90.72	.5149	.103449
60	9.477	10.48	89.52	.5081	.102089
120	9.447	10.75	89.25	.5065	.101773
180	9.492	10.33	89.67	.5089	.102249
240	9.544	9.84	90.16	.5117	.102813
300	9.522	10.05	89.95	.5105	.102572
360	9.550	9.78	90.22	.5121	.102882

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 35	LEFT VALVE				
3	9.143	9.32	90.68	.4902	.098496
60	9.085	9.90	90.10	.4871	.097875
120	9.135	9.41	90.59	.4898	.098405
180	9.112	9.63	90.37	.4886	.098165
240	9.078	9.97	90.03	.4867	.097795
300	9.095	9.80	90.20	.4876	.097974
360	9.137	9.38	90.62	.4899	.098434
RUN 36	RIGHT VALVE				
3	9.714	8.23	91.77	.5209	.104650
60	9.597	9.33	90.67	.5146	.103389
120	9.562	9.67	90.33	.5127	.103006
180	9.600	9.31	90.69	.5148	.103422
240	9.647	8.86	91.14	.5173	.103927
300	9.631	9.01	90.99	.5164	.103755
360	9.613	9.19	90.81	.5154	.103555
RUN 37	LEFT VALVE				
3	9.535	5.44	94.56	.5112	.102714
60	9.454	6.24	93.76	.5069	.101847
70	9.808	2.73	97.27	.5259	.105656
120	9.928	1.54	98.46	.5323	.106951
180	10.083	.00	100.00	.5406	.108624MAX
240	9.939	1.44	98.56	.5329	.107064
300	9.859	2.22	97.78	.5286	.106208
360	9.963	1.19	98.81	.5342	.107330

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 38	RIGHT VALVE				
3	10.138	4.23	95.77	.5436	.109212
60	10.044	5.11	94.89	.5385	.108202
120	9.930	6.19	93.81	.5324	.106976
180	10.040	5.15	94.85	.5383	.108156
240	10.103	4.56	95.44	.5417	.108833
300	10.082	4.76	95.24	.5406	.108609
360	10.131	4.29	95.71	.5432	.109141
RUN 39	LEFT VALVE				
3	9.213	8.63	91.37	.4940	.099246
60	9.149	9.27	90.73	.4905	.098558
120	9.163	9.12	90.88	.4913	.098712
180	9.155	9.21	90.79	.4908	.098620
240	9.068	10.07	89.93	.4862	.097684
300	9.086	9.89	90.11	.4872	.097878
360	9.031	10.44	89.56	.4842	.097287
RUN 40	RIGHT VALVE				
3	9.702	8.35	91.65	.5202	.104514
60	9.650	8.83	91.17	.5174	.103960
120	9.656	8.78	91.22	.5177	.104020
180	9.699	8.38	91.62	.5200	.104483
240	9.679	8.56	91.44	.5190	.104267
300	9.655	8.79	91.21	.5177	.104014
360	9.720	8.18	91.82	.5211	.104706

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 41	LEFT VALVE				
5	9.531	5.47	94.53	.5111	.102679
60	9.329	7.48	92.52	.5002	.100498
120	9.292	7.85	92.15	.4982	.100098
180	9.219	8.57	91.43	.4943	.099314
240	9.139	9.37	90.63	.4900	.098448
300	9.101	9.74	90.26	.4880	.098045
360	9.116	9.59	90.41	.4888	.098205
RUN 42	RIGHT VALVE				
1	10.094	4.65	95.35	.5412	.108736
60	10.043	5.13	94.87	.5385	.108189
120	9.925	6.24	93.76	.5322	.106920
180	9.944	6.06	93.94	.5332	.107128
240	9.868	6.78	93.22	.5291	.106305
300	9.850	6.95	93.05	.5282	.106114
380	9.831	7.12	92.88	.5271	.105910
405	9.771	7.69	92.31	.5239	.105262

APPENDIX IV

EQUIVALENT AREA AND FLOW VS. TIME PLOTS - NTO FLOW DECAY STUDY

This Appendix contains a graphical presentation of the equivalent area and system flow data vs. time collected during the flow test phase of Contract NAS 8-21489. A more complete presentation of this data including component inlet and outlet temperatures and pressure drops, in addition to the data presented in this Appendix, is presented in Appendix V. The flow variations in the flow data plotted in this Appendix may be partially due to variations in overall system pressure drop, however, this effect is relatively small. The effects of system pressure differential variation have been eliminated in calculating the equivalent area. The data plotted here should be used only to examine trends. If an actual value is desired for any data point, the tabular data in Appendix V must be used.

TIME SEC.	RIGHT ENGINE ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	LEFT ENGINE ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 21										
3	1.1676	10.90	89.10	.2425	.048715	1.2240	10.71	89.29	.2542	.051066
60	1.1694	10.76	89.24	.2428	.048792	1.2308	10.21	89.79	.2556	.051351
120	1.1640	11.17	88.83	.2417	.048564	1.2322	10.10	89.90	.2559	.051412
180	1.1640	11.17	88.83	.2417	.048564	1.2322	10.10	89.90	.2559	.051412
240	1.1951	8.80	91.20	.2482	.049861	1.2354	9.87	90.13	.2565	.051545
300	1.1794	9.99	90.01	.2449	.049208	1.2354	9.87	90.13	.2565	.051545
360	1.1902	9.17	90.83	.2472	.049660	1.2347	9.93	90.07	.2564	.051513
RUN 22										
2	1.2152	7.27	92.73	.2523	.050699	1.2462	9.08	90.92	.2588	.051995
60	1.2086	7.77	92.23	.2510	.050427	1.2379	9.69	90.31	.2571	.051647
120	1.2053	8.02	91.98	.2503	.050288	1.2321	10.11	89.89	.2559	.051406
180	1.2022	8.26	91.74	.2496	.050157	1.2326	10.08	89.92	.2560	.051426
240	1.2070	7.89	92.11	.2507	.050360	1.2228	10.79	89.21	.2539	.051016
300	1.2026	8.23	91.77	.2497	.050173	1.2301	10.26	89.74	.2554	.051323
360	1.2049	8.05	91.95	.2502	.050272	1.2304	10.23	89.77	.2555	.051336
RUN 23										
5	1.2062	7.95	92.05	.2505	.050324	1.2315	10.15	89.85	.2557	.051383
60	1.1980	8.58	91.42	.2488	.049984	1.2314	10.16	89.84	.2557	.051377
120	1.2003	8.40	91.60	.2493	.050079	1.2317	10.14	89.86	.2558	.051388
180	1.2022	8.26	91.74	.2496	.050158	1.2308	10.21	89.79	.2556	.051350
240	1.1988	8.52	91.48	.2489	.050015	1.2268	10.50	89.50	.2547	.051183
300	1.1927	8.98	91.02	.2477	.049764	1.2238	10.71	89.29	.2541	.051061
360	1.1927	8.98	91.02	.2477	.049764	1.2238	10.71	89.29	.2541	.051061

RIGHT ENGINE | LEFT ENGINE

TIME SEC.	RIGHT ACTUAL AREA SQ.IN. X1000	RIGHT DIFF FROM MAXIMUM PERCENT	RIGHT PERCENT OF MAXIMUM PERCENT	RIGHT CORRECTED GPM	RIGHT FLOW PPS	LEFT ACTUAL AREA SQ.IN. X1000	LEFT DIFF FROM MAXIMUM PERCENT	LEFT PERCENT OF MAXIMUM PERCENT	LEFT CORRECTED GPM	LEFT FLOW PPS
RUN 24										
1	1.2206	6.85	93.15	.2535	.050928	1.2642	7.77	92.23	.2625	.052747
2	1.2165	7.17	92.83	.2526	.050755	1.2368	9.77	90.23	.2568	.051601
60	1.2092	7.72	92.28	.2511	.050452	1.2487	8.90	91.10	.2593	.052097
61	1.2083	7.79	92.21	.2509	.050414	1.2449	9.18	90.82	.2585	.051938
62	1.2074	7.86	92.14	.2507	.050376	1.2306	10.22	89.78	.2555	.051343
120	1.2008	8.36	91.64	.2494	.050101	1.2276	10.44	89.56	.2549	.051217
180	1.2078	7.83	92.17	.2508	.050393	1.2286	10.37	89.63	.2551	.051258
240	1.2255	6.48	93.52	.2545	.051131	1.2298	10.28	89.72	.2554	.051309
300	1.2316	6.01	93.99	.2558	.051384	1.2302	10.25	89.75	.2555	.051326
360	1.2355	5.71	94.29	.2566	.051549	1.2303	10.25	89.75	.2555	.051330
RUN 25										
1	1.2511	4.53	95.47	.2598	.052198	1.2427	9.34	90.66	.2581	.051847
60	1.2482	4.75	95.25	.2592	.052077	1.2419	9.40	90.60	.2579	.051814
120	1.2425	5.18	94.82	.2580	.051840	1.2406	9.49	90.51	.2576	.051760
180	1.2442	5.05	94.95	.2584	.051909	1.2389	9.62	90.38	.2573	.051689
240	1.2393	5.42	94.58	.2574	.051707	1.2390	9.61	90.39	.2573	.051694
300	1.2410	5.29	94.71	.2577	.051778	1.2360	9.83	90.17	.2567	.051569
360	1.2367	5.62	94.38	.2568	.051599	1.2360	9.83	90.17	.2567	.051569
RUN 26										
1	1.2051	8.03	91.97	.2503	.050281	1.2465	9.06	90.94	.2588	.052005
4	1.2059	7.97	92.03	.2504	.050313	1.2209	10.93	89.07	.2535	.050940
15	1.2151	7.27	92.73	.2523	.050696	1.2169	11.22	88.78	.2527	.050770
60	1.2087	7.76	92.24	.2510	.050428	1.2242	10.69	89.31	.2542	.051075
120	1.2151	7.27	92.73	.2523	.050698	1.2256	10.59	89.41	.2545	.051133
200	1.2007	8.37	91.63	.2493	.050095	1.2206	10.95	89.05	.2535	.050927
260	1.2106	7.61	92.39	.2514	.050510	1.2257	10.58	89.42	.2545	.051140
300	1.2061	7.96	92.04	.2505	.050322	1.2277	10.43	89.57	.2549	.051223

	RIGHT ENGINE					LEFT ENGINE				
TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 27										
1	1.2218	6.76	93.24	.2537	.050977	1.2214	10.89	89.11	.2536	.050960
60	1.2218	6.76	93.24	.2537	.050977	1.2257	10.58	89.42	.2545	.051138
120	1.1980	8.58	91.42	.2488	.049984	1.2224	10.82	89.18	.2538	.051001
180	1.1926	8.99	91.01	.2476	.049756	1.2204	10.96	89.04	.2534	.050919
240	1.1680	10.86	89.14	.2426	.048733	1.2181	11.13	88.87	.2530	.050823
300	1.2052	8.03	91.97	.2503	.050284	1.2189	11.07	88.93	.2531	.050855
360	1.2061	7.96	92.04	.2505	.050323	1.2191	11.06	88.94	.2532	.050864
RUN 28										
2	1.2283	6.27	93.73	.2551	.051246	1.2329	10.05	89.95	.2560	.051440
25	1.2282	6.27	93.73	.2550	.051243	1.2276	10.44	89.56	.2549	.051218
29	1.2255	6.48	93.52	.2545	.051129	0.0000	100.00	0.00	0.0000	0.000000
54	1.2235	6.63	93.37	.2541	.051049	0.0000	100.00	0.00	0.0000	0.000000
57	0.0000	100.00	0.00	0.0000	0.000000	1.2413	9.44	90.56	.2578	.051788
81	0.0000	100.00	0.00	0.0000	0.000000	1.2322	10.10	89.90	.2559	.051410
RUN 29										
3	1.2147	7.30	92.70	.2522	.050681	1.2442	9.23	90.77	.2584	.051912
60	1.2142	7.34	92.66	.2522	.050661	1.2887	5.98	94.02	.2676	.053769
120	1.1722	10.55	89.45	.2434	.048905	1.3187	3.80	96.20	.2738	.055017
183	1.2152	7.27	92.73	.2523	.050700	1.2994	5.20	94.80	.2698	.054212
186	1.2288	6.22	93.78	.2552	.051269	1.3439	1.96	98.04	.2791	.056070
189	1.2141	7.35	92.65	.2521	.050656	1.3174	3.89	96.11	.2736	.054965
240	1.2285	6.25	93.75	.2551	.051257	1.3264	3.23	96.77	.2754	.055339
300	1.2138	7.37	92.63	.2520	.050641	1.3011	5.08	94.92	.2702	.054285
360	1.2129	7.44	92.56	.2519	.050604	1.2855	6.22	93.78	.2669	.053633

	RIGHT ENGINE					LEFT ENGINE				
TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 30										
3	1.2160	7.20	92.80	.2525	.050734	1.2178	11.16	88.84	.2529	.050809
20	1.1976	8.61	91.39	.2487	.049966	1.2163	11.26	88.74	.2526	.050749
33	1.2231	6.66	93.34	.2540	.051032	1.2884	6.01	93.99	.2675	.053754
36	1.2181	7.05	92.95	.2529	.050820	1.3276	3.14	96.86	.2757	.055392
55	1.2221	6.74	93.26	.2538	.050988	1.3291	3.03	96.97	.2760	.055455
120	1.2174	7.10	92.90	.2528	.050792	1.3039	4.88	95.12	.2708	.054400
180	1.2159	7.21	92.79	.2525	.050729	1.3084	4.54	95.46	.2717	.054590
240	1.2265	6.40	93.60	.2547	.051171	1.3064	4.69	95.31	.2713	.054508
300	1.2225	6.71	93.29	.2539	.051006	1.3069	4.65	95.35	.2714	.054529
360	1.2334	5.88	94.12	.2561	.051460	1.3134	4.18	95.82	.2727	.054800
RUN 31										
3	1.2533	4.36	95.64	.2603	.052290	1.3213	3.61	96.39	.2744	.055127
60	1.2439	5.07	94.93	.2583	.051899	1.3207	3.65	96.35	.2743	.055103
120	1.2258	6.45	93.55	.2546	.051145	1.3257	3.28	96.72	.2753	.055311
180	1.2503	4.59	95.41	.2596	.052163	1.3547	1.17	98.83	.2813	.056519
250	1.2417	5.24	94.76	.2579	.051808	1.2886	5.99	94.01	.2676	.053763
300	1.2422	5.21	94.79	.2579	.051825	1.2364	9.80	90.20	.2568	.051585
350	1.2242	6.58	93.42	.2542	.051075	1.2225	10.81	89.19	.2539	.051005
360	1.2444	5.04	94.96	.2584	.051918	1.2221	10.84	89.16	.2538	.050987
RUN 32										
3	1.2482	4.75	95.25	.2592	.052077	1.2266	10.51	89.49	.2547	.051178
17	1.2412	5.28	94.72	.2577	.051785	1.2315	10.15	89.85	.2557	.051383
19	1.2192	6.96	93.04	.2532	.050870	1.2320	10.12	89.88	.2558	.051401
23	1.2446	5.02	94.98	.2585	.051929	1.2495	8.84	91.16	.2595	.052133
33	1.2575	4.04	95.96	.2611	.052464	1.2949	5.53	94.47	.2689	.054028
50	1.2596	3.88	96.12	.2616	.052551	1.3344	2.65	97.35	.2771	.055676
110	1.2565	4.11	95.89	.2609	.052423	1.3068	4.66	95.34	.2714	.054521
180	1.2522	4.44	95.56	.2600	.052243	1.2797	6.64	93.36	.2658	.053394

	RIGHT ENGINE					LEFT ENGINE				
TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 32 CONTINUED										
240	1.2489	4.69	95.31	.2593	.052106	1.2879	6.04	93.96	.2674	.053734
300	1.2538	4.32	95.68	.2604	.052310	1.2854	6.23	93.77	.2669	.053628
360	1.2449	5.00	95.00	.2585	.051938	1.2764	6.88	93.12	.2651	.053256
362	1.2480	4.76	95.24	.2592	.052068	1.3066	4.68	95.32	.2713	.054515
RUN 33										
3	1.2163	7.18	92.82	.2526	.050747	1.2214	10.89	89.11	.2536	.050961
10	1.2185	7.01	92.99	.2530	.050839	1.2199	11.00	89.00	.2533	.050896
60	1.2135	7.39	92.61	.2520	.050631	1.2174	11.19	88.81	.2528	.050791
120	1.2145	7.32	92.68	.2522	.050671	1.2180	11.14	88.86	.2529	.050816
180	1.2140	7.36	92.64	.2521	.050651	1.2205	10.95	89.05	.2535	.050924
240	1.2154	7.25	92.75	.2524	.050710	1.2207	10.94	89.06	.2535	.050931
300	1.2130	7.43	92.57	.2519	.050609	1.2219	10.86	89.14	.2537	.050979
360	1.2142	7.34	92.66	.2521	.050660	1.2168	11.23	88.77	.2527	.050766
RUN 34										
3	1.2205	6.86	93.14	.2534	.050921	1.2199	11.00	89.00	.2533	.050896
60	1.2144	7.32	92.68	.2522	.050669	1.2192	11.06	88.94	.2532	.050866
120	1.2146	7.31	92.69	.2522	.050676	1.2170	11.21	88.79	.2527	.050777
180	1.2097	7.68	92.32	.2512	.050473	1.2149	11.36	88.64	.2523	.050690
240	1.2088	7.75	92.25	.2510	.050434	1.2165	11.25	88.75	.2526	.050757
300	1.2147	7.30	92.70	.2522	.050680	1.2144	11.40	88.60	.2522	.050667
360	1.2165	7.16	92.84	.2526	.050756	1.2170	11.21	88.79	.2527	.050776

	RIGHT ENGINE					LEFT ENGINE				
TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 35										
3	1.2285	6.25	93.75	.2551	.051257	1.2161	11.28	88.72	.2525	.050737
60	1.2213	6.80	93.20	.2536	.050955	1.2147	11.38	88.62	.2522	.050680
120	1.2205	6.86	93.14	.2535	.050924	1.2146	11.39	88.61	.2522	.050676
180	1.2216	6.77	93.23	.2537	.050969	1.2146	11.39	88.61	.2522	.050676
240	1.2118	7.52	92.48	.2516	.050558	1.2144	11.40	88.60	.2522	.050669
300	1.2148	7.30	92.70	.2523	.050682	1.2153	11.34	88.66	.2524	.050703
360	1.2157	7.23	92.77	.2524	.050721	1.2140	11.43	88.57	.2521	.050652
RUN 36										
3	1.2253	6.49	93.51	.2544	.051123	1.2122	11.56	88.44	.2517	.050577
60	1.2158	7.22	92.78	.2525	.050726	1.2076	11.90	88.10	.2508	.050383
120	1.2097	7.68	92.32	.2512	.050473	1.2080	11.87	88.13	.2509	.050400
180	1.2136	7.38	92.62	.2520	.050636	1.2126	11.54	88.46	.2518	.050590
240	1.2230	6.67	93.33	.2540	.051027	1.2101	11.72	88.28	.2513	.050489
300	1.2265	6.40	93.60	.2547	.051174	1.2121	11.57	88.43	.2517	.050573
360	1.2248	6.53	93.47	.2543	.051102	1.2134	11.48	88.52	.2520	.050625
RUN 37										
3	1.2472	4.83	95.17	.2590	.052034	1.2275	10.45	89.55	.2549	.051214
60	1.2489	4.69	95.31	.2593	.052107	1.2173	11.19	88.81	.2528	.050787
70	1.2491	4.67	95.33	.2594	.052117	1.2865	6.15	93.85	.2671	.053674
120	1.2485	4.73	95.27	.2593	.052089	1.3339	2.69	97.31	.2770	.055653
180	1.2460	4.91	95.09	.2588	.051988	1.3707	.00	100.00	.2846	.057189
240	1.2483	4.74	95.26	.2592	.052082	1.3278	3.13	96.87	.2757	.055398
300	1.2492	4.67	95.33	.2594	.052118	1.3113	4.33	95.67	.2723	.054711
360	1.2527	4.40	95.60	.2601	.052267	1.3223	3.53	96.47	.2746	.055169

	RIGHT ENGINE					LEFT ENGINE				
TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 38										
3	1.2569	4.09	95.91	.2610	.052439	1.3486	1.62	98.38	.2800	.056265
60	1.2472	4.82	95.18	.2590	.052038	1.3329	2.76	97.24	.2768	.055611
120	1.2442	5.05	94.95	.2584	.051911	1.3043	4.85	95.15	.2708	.054416
180	1.2473	4.81	95.19	.2590	.052040	1.3315	2.86	97.14	.2765	.055552
240	1.2433	5.12	94.88	.2582	.051875	1.3479	1.67	98.33	.2799	.056236
300	1.2421	5.21	94.79	.2579	.051822	1.3479	1.67	98.33	.2799	.056236
360	1.2452	4.98	95.02	.2586	.051951	1.3517	1.38	98.62	.2807	.056397
RUN 39										
3	1.2194	6.94	93.06	.2532	.050878	1.2265	10.52	89.48	.2547	.051172
60	1.2317	6.01	93.99	.2558	.051387	1.2238	10.72	89.28	.2541	.051059
120	1.2302	6.12	93.88	.2555	.051325	1.2258	10.57	89.43	.2545	.051142
180	1.2277	6.31	93.69	.2549	.051222	1.2263	10.54	89.46	.2547	.051164
240	1.2249	6.52	93.48	.2544	.051107	1.2293	10.32	89.68	.2553	.051289
300	1.2240	6.59	93.41	.2542	.051069	1.2294	10.31	89.69	.2553	.051293
360	1.2254	6.49	93.51	.2545	.051125	1.2269	10.49	89.51	.2548	.051187
RUN 40										
3	1.2286	6.24	93.76	.2551	.051261	1.2212	10.91	89.09	.2536	.050952
60	1.2281	6.28	93.72	.2550	.051238	1.2170	11.21	88.79	.2527	.050777
120	1.2255	6.48	93.52	.2545	.051129	1.2144	11.40	88.60	.2522	.050669
180	1.2219	6.76	93.24	.2537	.050979	1.2176	11.17	88.83	.2528	.050801
240	1.2302	6.12	93.88	.2555	.051326	1.2167	11.24	88.76	.2527	.050764
300	1.2281	6.28	93.72	.2550	.051240	1.2122	11.57	88.43	.2517	.050574
360	1.2285	6.25	93.75	.2551	.051257	1.2118	11.60	88.40	.2516	.050557

TIME SEC.	RIGHT ENGINE ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS	LEFT ENGINE ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 41										
5	1.2677	3.26	96.74	.2632	.052890	1.2234	10.75	89.25	.2540	.051042
60	1.2788	2.41	97.59	.2656	.053356	1.2311	10.19	89.81	.2556	.051363
120	1.2757	2.65	97.35	.2649	.053225	1.2271	10.48	89.52	.2548	.051196
180	1.2717	2.95	97.05	.2641	.053059	1.2234	10.75	89.25	.2540	.051042
240	1.2541	4.30	95.70	.2604	.052322	1.2269	10.49	89.51	.2548	.051188
300	1.2509	4.54	95.46	.2598	.052189	1.2240	10.70	89.30	.2542	.051069
360	1.2493	4.66	95.34	.2594	.052124	1.2225	10.81	89.19	.2539	.051004
RUN 42										
1	1.2332	5.89	94.11	.2561	.051453	1.2394	9.58	90.42	.2574	.051711
60	1.2292	6.20	93.80	.2552	.051284	1.2294	10.31	89.69	.2553	.051295
120	1.2307	6.08	93.92	.2556	.051347	1.2333	10.02	89.98	.2561	.051458
180	1.2230	6.67	93.33	.2540	.051025	1.2282	10.40	89.60	.2551	.051244
240	1.2250	6.52	93.48	.2544	.051108	1.2393	9.59	90.41	.2573	.051705
300	1.2361	5.67	94.33	.2567	.051574	1.2381	9.68	90.32	.2571	.051655
380	1.2356	5.70	94.30	.2566	.051554	1.2372	9.74	90.26	.2569	.051618
405	1.2248	6.53	93.47	.2543	.051101	1.2315	10.15	89.85	.2557	.051381

ISOLATION VALVE

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 2 BOTH VALVES					
3	12.726	35.57	64.43	.3412	.068547
10	15.840	19.81	80.19	.4246	.085319
15	15.185	23.12	76.88	.4071	.081792
20	16.081	18.59	81.41	.4311	.086617
30	16.081	18.59	81.41	.4311	.086617
45	14.735	25.40	74.60	.3950	.079367
60	14.675	25.71	74.29	.3934	.079042
120	14.559	26.29	73.71	.3903	.078419
180	15.644	20.80	79.20	.4194	.084263
240	16.149	18.24	81.76	.4329	.086982
300	16.976	14.05	85.95	.4551	.091439
360	16.942	14.23	85.77	.4542	.091253
635	14.114	28.54	71.46	.3784	.076022
705	13.998	29.13	70.87	.3753	.075400
942	13.889	29.68	70.32	.3723	.074810
1275	14.640	25.88	74.12	.3925	.078855
RUN 3 BOTH VALVES					
5	13.975	29.25	70.75	.3746	.075272
45	14.279	27.71	72.29	.3828	.076909
67	15.470	21.68	78.32	.4147	.083325
225	14.580	26.18	73.82	.3909	.078534
605	14.230	27.96	72.04	.3815	.076645
635	14.642	25.87	74.13	.3925	.078869
775	15.203	23.03	76.97	.4076	.081888
1105	14.906	24.54	75.46	.3996	.080286

ISOLATION VALVE

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 4 BOTH VALVES					
40	14.650	25.83	74.17	.3928	.078910
75	14.438	26.90	73.10	.3871	.077766
120	14.491	26.63	73.37	.3885	.078054
180	14.092	28.65	71.35	.3778	.075904
240	13.856	29.85	70.15	.3715	.074633
300	14.249	27.86	72.14	.3820	.076750
360	14.012	29.06	70.94	.3757	.075475
420	14.105	28.59	71.41	.3781	.075973
480	13.948	29.38	70.62	.3739	.075128
540	13.866	29.80	70.20	.3717	.074685
600	13.993	29.16	70.84	.3751	.075370
RUN 5 BOTH VALVES					
15	14.521	26.48	73.52	.3893	.078214
19	14.029	28.98	71.02	.3761	.075563
30	14.090	28.66	71.34	.3777	.075894
55	16.327	17.34	82.66	.4377	.087940
190	13.964	29.30	70.70	.3744	.075215
270	13.695	30.67	69.33	.3671	.073764
460	13.372	32.30	67.70	.3585	.072025
600	13.323	32.55	67.45	.3572	.071762
RUN 6 BOTH VALVES					
8	13.063	33.87	66.13	.3502	.070359
28	13.996	29.14	70.86	.3752	.075385
120	13.860	29.83	70.17	.3716	.074653
360	12.732	35.54	64.46	.3413	.068580
600	12.501	36.71	63.29	.3351	.067335MIN

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 7 BOTH VALVES					
-1	0.000	100.00	0.00	0.0000	0.000000
0	13.877	29.74	70.26	.3720	.074746
4	14.669	25.73	74.27	.3933	.079014
7	15.505	21.50	78.50	.4157	.083514
10	15.787	20.08	79.92	.4232	.085032
13	16.051	18.74	81.26	.4303	.086457
18	15.907	19.47	80.53	.4264	.085678
22	15.716	20.43	79.57	.4213	.084653
27	15.625	20.90	79.10	.4189	.084160
34	15.736	20.33	79.67	.4219	.084761
39	15.721	20.41	79.59	.4215	.084679
56	15.345	22.31	77.69	.4114	.082653
72	15.193	23.08	76.92	.4073	.081832
110	15.212	22.98	77.02	.4078	.081939
142	15.126	23.42	76.58	.4055	.081473
201	15.052	23.79	76.21	.4035	.081076
289	15.093	23.58	76.42	.4046	.081298
348	15.177	23.16	76.84	.4069	.081748
407	15.246	22.81	77.19	.4087	.082117
600	15.291	22.59	77.41	.4099	.082361
RUN 8 BOTH VALVES					
5	19.072	3.44	96.56	.5113	.102727
20	19.005	3.78	96.22	.5095	.102369
40	18.953	4.04	95.96	.5081	.102089
60	18.975	3.93	96.07	.5087	.102207
80	19.019	3.71	96.29	.5099	.102441
100	19.008	3.77	96.23	.5096	.102383

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 9 BOTH VALVES					
3	19.752	.00	100.00	.5295	.106390MAX
60	19.561	.97	99.03	.5244	.105362
120	19.567	.94	99.06	.5246	.105392
180	19.507	1.24	98.76	.5229	.105069
500	19.008	3.77	96.23	.5096	.102381
560	18.956	4.03	95.97	.5082	.102102
620	18.958	4.02	95.98	.5082	.102115
RUN 10 BOTH VALVES					
350	17.560	11.10	88.90	.4708	.094584
420	17.482	11.49	88.51	.4687	.094166
470	17.449	11.66	88.34	.4678	.093986
RUN 12 BOTH VALVES					
3	18.588	5.89	94.11	.4983	.100122
13	18.727	5.19	94.81	.5021	.100870
30	18.918	4.22	95.78	.5072	.101897
60	19.152	3.04	96.96	.5134	.103157
120	19.098	3.31	96.69	.5120	.102870
180	18.968	3.97	96.03	.5085	.102169
RUN 13 BOTH VALVES					
260	18.021	8.76	91.24	.4831	.097069
320	18.179	7.96	92.04	.4874	.097919
400	18.085	8.44	91.56	.4848	.097410
500	17.955	9.10	90.90	.4814	.096713

ISOLATION VALVE

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 14 BOTH VALVES					
4	17.927	9.24	90.76	.4806	.096558
20	17.918	9.28	90.72	.4804	.096514
30	17.930	9.23	90.77	.4807	.096575
50	18.007	8.84	91.16	.4827	.096989
60	17.997	8.88	91.12	.4825	.096937
120	17.864	9.56	90.44	.4789	.096222
180	17.713	10.32	89.68	.4749	.095409
240	17.759	10.09	89.91	.4761	.095653
300	17.702	10.38	89.62	.4746	.095346
RUN 15 RIGHT VALVE					
120	10.059	4.97	95.03	.5394	.108364
180	9.932	6.17	93.83	.5325	.106994
250	9.981	5.71	94.29	.5352	.107524
400	9.646	8.88	91.12	.5172	.103911
RUN 16 RIGHT VALVE					
115	7.018	33.70	66.30	.3763	.075602
171	6.811	35.66	64.34	.3652	.073370
226	6.803	35.74	64.26	.3647	.073284MIN
RUN 17 LEFT VALVE					
10	8.015	20.51	79.49	.4297	.086340
23	7.974	20.92	79.08	.4275	.085901
40	7.553	25.10	74.90	.4050	.081362MIN
80	7.650	24.14	75.86	.4102	.082407
150	7.830	22.35	77.65	.4198	.084345
300	7.828	22.37	77.63	.4197	.084329

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 18 RIGHT VALVE					
56	9.648	8.86	91.14	.5173	.103935
120	9.546	9.82	90.18	.5118	.102835
182	9.491	10.34	89.66	.5089	.102248
245	9.562	9.67	90.33	.5127	.103010
300	9.627	9.06	90.94	.5162	.103708
400	9.507	10.19	89.81	.5098	.102420
480	9.454	10.69	89.31	.5069	.101843
550	9.450	10.73	89.27	.5067	.101799
570	9.461	10.62	89.38	.5073	.101922
RUN 19 LEFT VALVE					
10	9.275	8.02	91.98	.4973	.099912
70	9.174	9.01	90.99	.4919	.098833
240	9.203	8.73	91.27	.4935	.099144
270	9.203	8.73	91.27	.4935	.099144
420	9.147	9.29	90.71	.4904	.098535
496	9.198	8.78	91.22	.4932	.099091
560	9.163	9.12	90.88	.4913	.098712
610	9.205	8.71	91.29	.4935	.099158
RUN 20 RIGHT VALVE					
60	9.303	12.12	87.88	.4988	.100218
120	9.336	11.80	88.20	.5006	.100575
380	9.373	11.45	88.55	.5026	.100972
240	9.369	11.49	88.51	.5024	.100933
300	9.377	11.42	88.58	.5027	.101010
360	9.409	11.11	88.89	.5045	.101364

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 21	LEFT VALVE				
3	9.222	8.54	91.46	.4945	.099344
60	9.171	9.05	90.95	.4917	.098791
120	9.254	8.23	91.77	.4962	.099689
180	9.237	8.40	91.60	.4953	.099504
240	9.349	7.28	92.72	.5013	.100713
300	9.119	9.56	90.44	.4889	.098236
360	9.248	8.28	91.72	.4959	.099628
RUN 22	RIGHT VALVE				
2	9.799	7.43	92.57	.5254	.105565
60	9.872	6.74	93.26	.5293	.106349
120	9.819	7.24	92.76	.5265	.105781
180	9.769	7.71	92.29	.5238	.105239
240	9.682	8.53	91.47	.5191	.104304
300	9.840	7.04	92.96	.5276	.106005
360	9.829	7.15	92.85	.5270	.105880
RUN 23	LEFT VALVE				
5	9.392	6.86	93.14	.5036	.101173
60	9.465	6.14	93.86	.5075	.101959
120	9.472	6.07	93.93	.5078	.102035
180	9.479	6.00	94.00	.5082	.102112
240	9.468	6.11	93.89	.5076	.101992
300	9.407	6.71	93.29	.5044	.101335
360	9.389	6.89	93.11	.5034	.101144

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 24	RIGHT VALVE				
1	10.049	5.07	94.93	.5388	.108250
2	9.896	6.51	93.49	.5306	.106610
60	9.904	6.44	93.56	.5310	.106695
61	9.872	6.74	93.26	.5293	.106345
62	9.803	7.39	92.61	.5256	.105609
120	9.788	7.53	92.47	.5248	.105444
180	9.803	7.39	92.61	.5256	.105609
240	9.890	6.57	93.43	.5303	.106541
300	9.890	6.57	93.43	.5303	.106541
360	9.833	7.11	92.89	.5272	.105924
RUN 25	LEFT VALVE				
1	9.716	3.64	96.36	.5209	.104666
60	9.678	4.02	95.98	.5189	.104254
120	9.660	4.19	95.81	.5180	.104068
180	9.630	4.49	95.51	.5163	.103742
240	9.502	5.77	94.23	.5095	.102360
300	9.510	5.69	94.31	.5099	.102444
360	9.511	5.67	94.33	.5100	.102462
RUN 26	RIGHT VALVE				
1	9.939	6.11	93.89	.5329	.107071
4	9.833	7.11	92.89	.5272	.105922
15	9.936	6.14	93.86	.5327	.107037
60	9.870	6.76	93.24	.5292	.106326
120	9.873	6.74	93.26	.5293	.106353
200	9.908	6.40	93.60	.5312	.106735
260	9.939	6.11	93.89	.5329	.107067
300	9.912	6.36	93.64	.5315	.106783

I S O L A T I O N   V A L V E

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
R U N 27	LEFT VALVE				
1	9.575	5.04	94.96	.5134	.103152
60	9.540	5.39	94.61	.5115	.102773
120	9.493	5.86	94.14	.5090	.102264
180	9.432	6.46	93.54	.5057	.101608
240	9.516	5.63	94.37	.5102	.102513
300	9.535	5.44	94.56	.5112	.102714
360	9.496	5.82	94.18	.5092	.102301
R U N 28	BOTH VALVES				
2	17.731	10.23	89.77	.4753	.095504
25	17.840	9.68	90.32	.4783	.096093
29	16.509	16.42	83.58	.4426	.088921
54	16.509	16.42	83.58	.4426	.088921
57	16.632	15.79	84.21	.4459	.089587
81	16.516	16.38	83.62	.4428	.088961
R U N 29	LEFT VALVE				
3	9.138	9.38	90.62	.4899	.098438
60	9.317	7.60	92.40	.4995	.100364
120	9.294	7.83	92.17	.4983	.100115
183	9.328	7.49	92.51	.5001	.100488
186	9.538	5.41	94.59	.5114	.102744
189	9.383	6.94	93.06	.5031	.101082
240	9.406	6.71	93.29	.5044	.101332
300	9.187	8.89	91.11	.4926	.098968
360	9.181	8.95	91.05	.4923	.098905

I S O L A T I O N   V A L V E

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
R U N 30	RIGHT VALVE				
3	9.660	8.74	91.26	.5180	.104066
20	9.606	9.25	90.75	.5151	.103486
33	9.968	5.83	94.17	.5345	.107383
36	10.151	4.11	95.89	.5443	.109350
55	10.157	4.05	95.95	.5446	.109412
120	10.003	5.50	94.50	.5363	.107759
180	10.024	5.30	94.70	.5375	.107990
240	10.069	4.88	95.12	.5399	.108471
300	10.046	5.10	94.90	.5387	.108224
360	10.194	3.70	96.30	.5466	.109812
R U N 31	LEFT VALVE				
3	9.703	3.77	96.23	.5202	.104525
60	9.762	3.19	96.81	.5234	.105159
120	9.667	4.13	95.87	.5183	.104138
180	9.823	2.58	97.42	.5267	.105823
250	9.332	7.45	92.55	.5004	.100529
300	9.107	9.68	90.32	.4883	.098109
350	8.963	11.11	88.89	.4806	.096554
360	9.036	10.39	89.61	.4845	.097343
R U N 32	RIGHT VALVE				
3	10.289	2.80	97.20	.5517	.110839
17	10.272	2.96	97.04	.5508	.110661
19	10.191	3.73	96.27	.5464	.109783
23	10.367	2.07	97.93	.5558	.111677
33	10.499	.81	99.19	.5629	.113105
50	10.586	.00	100.00	.5676	.114034MAX
110	10.380	1.94	98.06	.5565	.111818
180	10.237	3.29	96.71	.5489	.110280

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 32	RIGHT VALVE		CONTINUED		
240	10.322	2.49	97.51	.5535	.111199
300	10.337	2.35	97.65	.5542	.111357
360	10.250	3.17	96.83	.5496	.110416
362	10.405	1.71	98.29	.5579	.112085
RUN 33	LEFT VALVE				
3	8.879	11.94	88.06	.4761	.095652
10	8.882	11.91	88.09	.4762	.095685
60	8.915	11.59	88.41	.4780	.096033
120	8.872	12.01	87.99	.4757	.095580
180	8.898	11.75	88.25	.4771	.095857
240	8.876	11.97	88.03	.4759	.095623
300	8.930	11.44	88.56	.4788	.096199
360	8.856	12.17	87.83	.4748	.095401
RUN 34	RIGHT VALVE				
3	9.603	9.28	90.72	.5149	.103449
60	9.477	10.48	89.52	.5081	.102089
120	9.447	10.75	89.25	.5065	.101773
180	9.492	10.33	89.67	.5089	.102249
240	9.544	9.84	90.16	.5117	.102813
300	9.522	10.05	89.95	.5105	.102572
360	9.550	9.78	90.22	.5121	.102882

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 35	LEFT VALVE				
3	9.143	9.32	90.68	.4902	.098496
60	9.085	9.90	90.10	.4871	.097875
120	9.135	9.41	90.59	.4898	.098405
180	9.112	9.63	90.37	.4886	.098165
240	9.078	9.97	90.03	.4867	.097795
300	9.095	9.80	90.20	.4876	.097974
360	9.137	9.38	90.62	.4899	.098434
RUN 36	RIGHT VALVE				
3	9.714	8.23	91.77	.5209	.104650
60	9.597	9.33	90.67	.5146	.103389
120	9.562	9.67	90.33	.5127	.103006
180	9.600	9.31	90.69	.5148	.103422
240	9.647	8.86	91.14	.5173	.103927
300	9.631	9.01	90.99	.5164	.103755
360	9.613	9.19	90.81	.5154	.103555
RUN 37	LEFT VALVE				
3	9.535	5.44	94.56	.5112	.102714
60	9.454	6.24	93.76	.5069	.101847
70	9.808	2.73	97.27	.5259	.105656
120	9.928	1.54	98.46	.5323	.106951
180	10.083	.00	100.00	.5406	.108624MAX
240	9.939	1.44	98.56	.5329	.107064
300	9.859	2.22	97.78	.5286	.106208
360	9.963	1.19	98.81	.5342	.107330

ISOLATION VALVE

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 38	RIGHT VALVE				
3	10.138	4.23	95.77	.5436	.109212
60	10.044	5.11	94.89	.5385	.108202
120	9.930	6.19	93.81	.5324	.106976
180	10.040	5.15	94.85	.5383	.108156
240	10.103	4.56	95.44	.5417	.108833
300	10.082	4.76	95.24	.5406	.108609
360	10.131	4.29	95.71	.5432	.109141
RUN 39	LEFT VALVE				
3	9.213	8.63	91.37	.4940	.099246
60	9.149	9.27	90.73	.4905	.098558
120	9.163	9.12	90.88	.4913	.098712
180	9.155	9.21	90.79	.4908	.098620
240	9.068	10.07	89.93	.4862	.097684
300	9.086	9.89	90.11	.4872	.097878
360	9.031	10.44	89.56	.4842	.097287
RUN 40	RIGHT VALVE				
3	9.702	8.35	91.65	.5202	.104514
60	9.650	8.83	91.17	.5174	.103960
120	9.656	8.78	91.22	.5177	.104020
180	9.699	8.38	91.62	.5200	.104483
240	9.679	8.56	91.44	.5190	.104267
300	9.655	8.79	91.21	.5177	.104014
360	9.720	8.18	91.82	.5211	.104706

ISOLATION VALVE

TIME SEC.	ACTUAL AREA SQ.IN. X1000	DIFF FROM MAXIMUM PERCENT	PERCENT OF MAXIMUM PERCENT	CORRECTED GPM	FLOW PPS
RUN 41	LEFT VALVE				
5	9.531	5.47	94.53	.5111	.102679
60	9.329	7.48	92.52	.5002	.100498
120	9.292	7.85	92.15	.4982	.100098
180	9.219	8.57	91.43	.4943	.099314
240	9.139	9.37	90.63	.4900	.098448
300	9.101	9.74	90.26	.4880	.098045
360	9.116	9.59	90.41	.4888	.098205
RUN 42	RIGHT VALVE				
1	10.094	4.65	95.35	.5412	.108736
60	10.043	5.13	94.87	.5385	.108189
120	9.925	6.24	93.76	.5322	.106920
180	9.944	6.06	93.94	.5332	.107128
240	9.868	6.78	93.22	.5291	.106305
300	9.850	6.95	93.05	.5282	.106114
380	9.831	7.12	92.88	.5271	.105910
405	9.771	7.69	92.31	.5239	.105262

APPENDIX IV

EQUIVALENT AREA AND FLOW VS. TIME PLOTS - NTO FLOW DECAY STUDY

This Appendix contains a graphical presentation of the equivalent area and system flow data vs. time collected during the flow test phase of Contract NAS 8-21489. A more complete presentation of this data including component inlet and outlet temperatures and pressure drops, in addition to the data presented in this Appendix, is presented in Appendix V. The flow variations in the flow data plotted in this Appendix may be partially due to variations in overall system pressure drop, however, this effect is relatively small. The effects of system pressure differential variation have been eliminated in calculating the equivalent area. The data plotted here should be used only to examine trends. If an actual value is desired for any data point, the tabular data in Appendix V must be used.

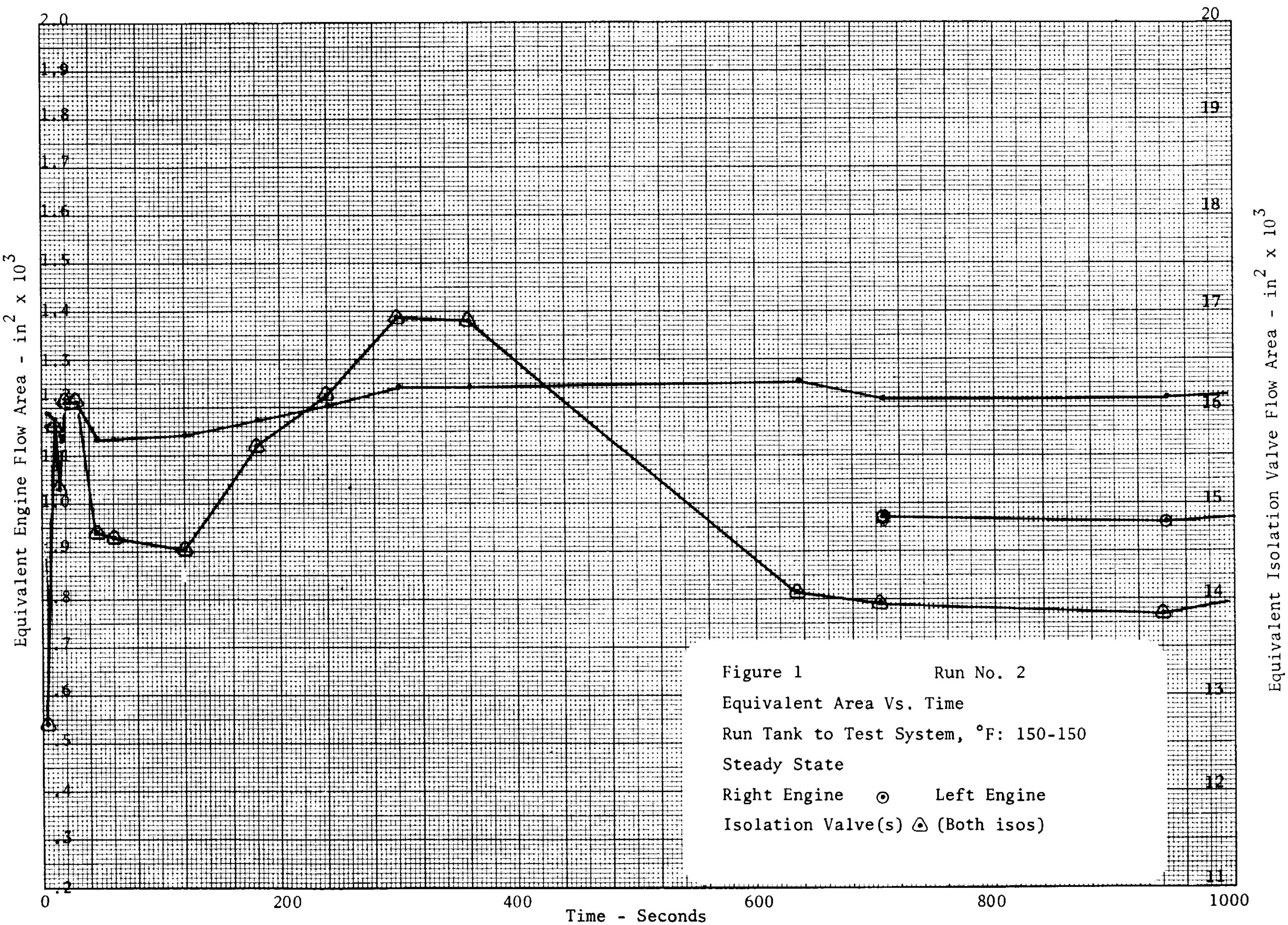


Figure 1 Run No. 2

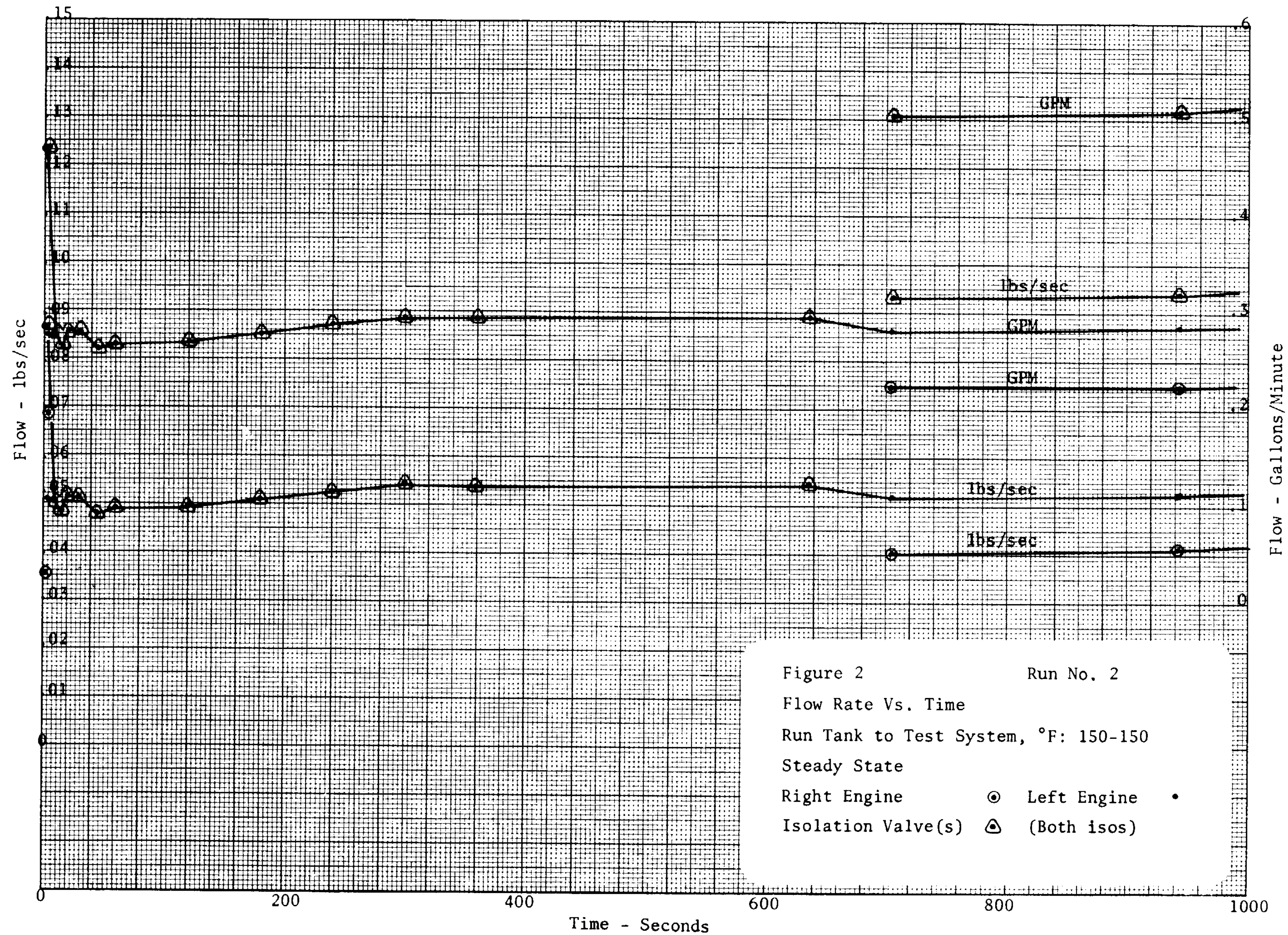
Equivalent Area Vs. Time

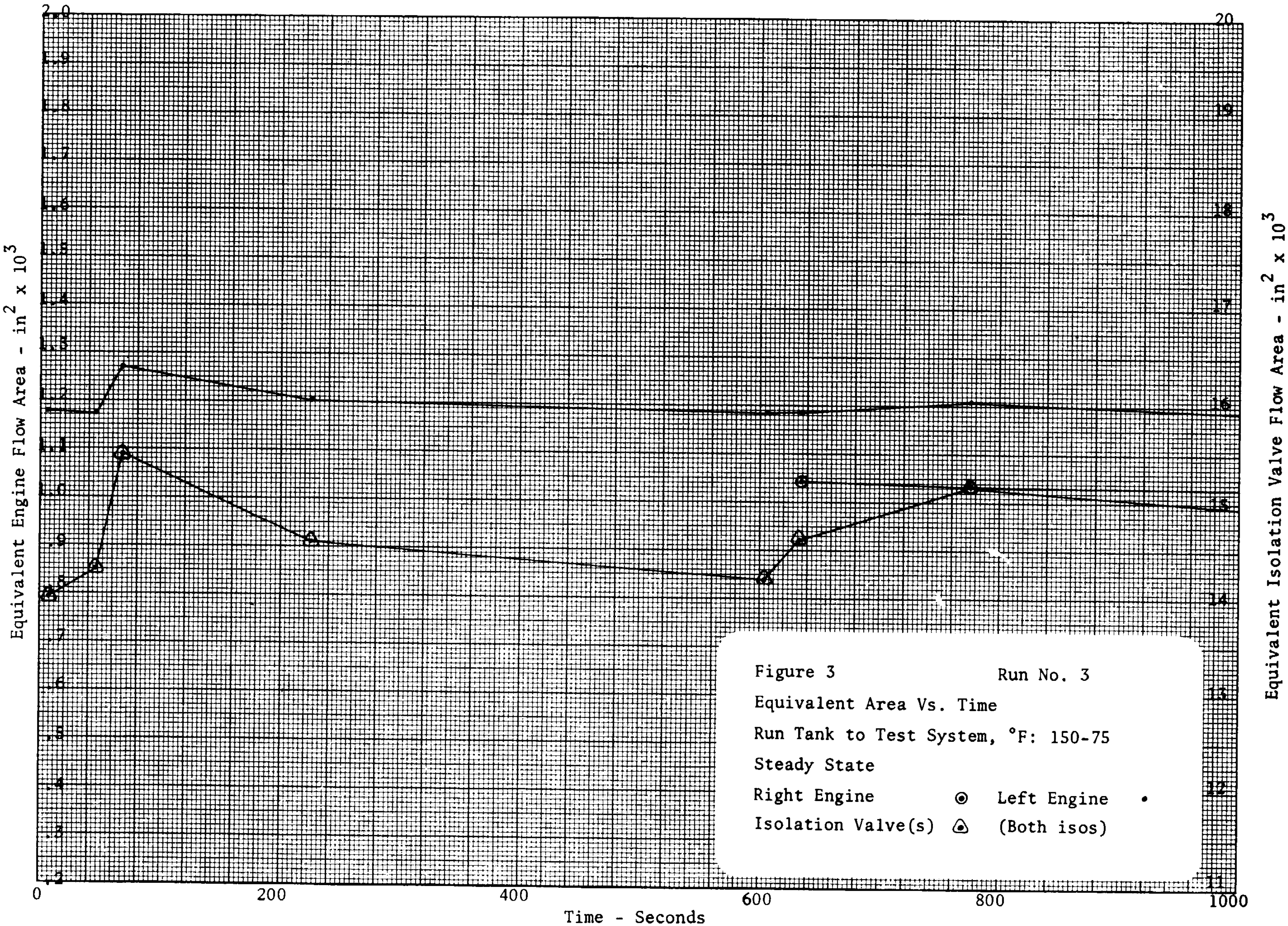
Run Tank to Test System, °F: 150-150

Steady State

Right Engine ⊙ Left Engine

Isolation Valve(s) △ (Both isos)


Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
GPM
lbs/sec
GPM
GPM
lbs/sec
lbs/sec
Figure 2
Run No. 2
Flow Rate Vs. Time
Run Tank to Test System, °F: 150-150
Steady State
Right Engine ⊙ Left Engine •
Isolation Valve(s) (Both isos)


Equivalent Engine Flow Area - $in^2 \times 10^3$
Equivalent Isolation Valve Flow Area - $in^2 \times 10^3$
Time - Seconds
0
200
400
600
800
1000
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
20
19
18
17
16
15
14
13
12
11
Figure 3
Run No. 3
Equivalent Area Vs. Time
Run Tank to Test System, °F: 150-75
Steady State
Right Engine
Left Engine
Isolation Valve(s)
(Both isos)

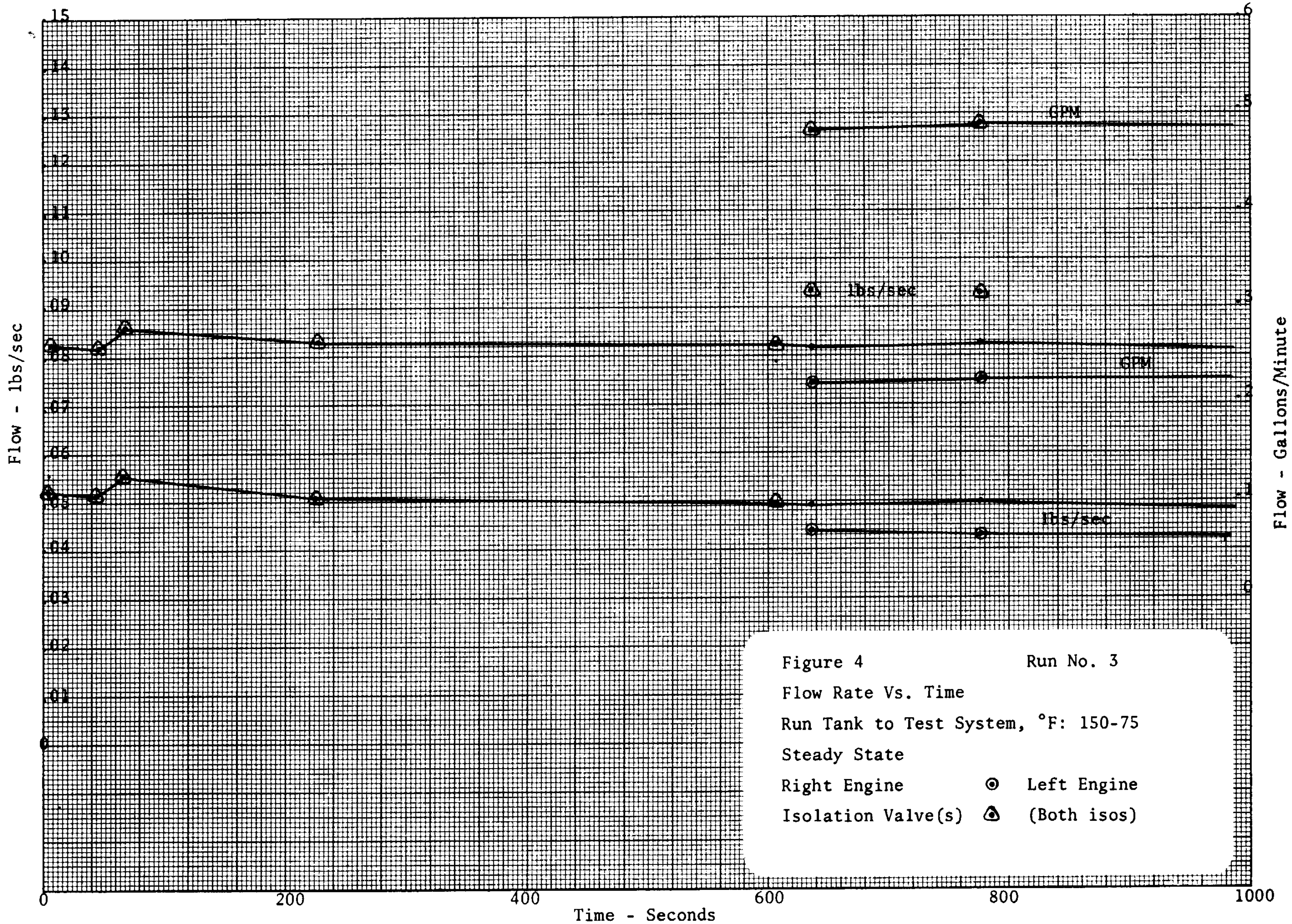
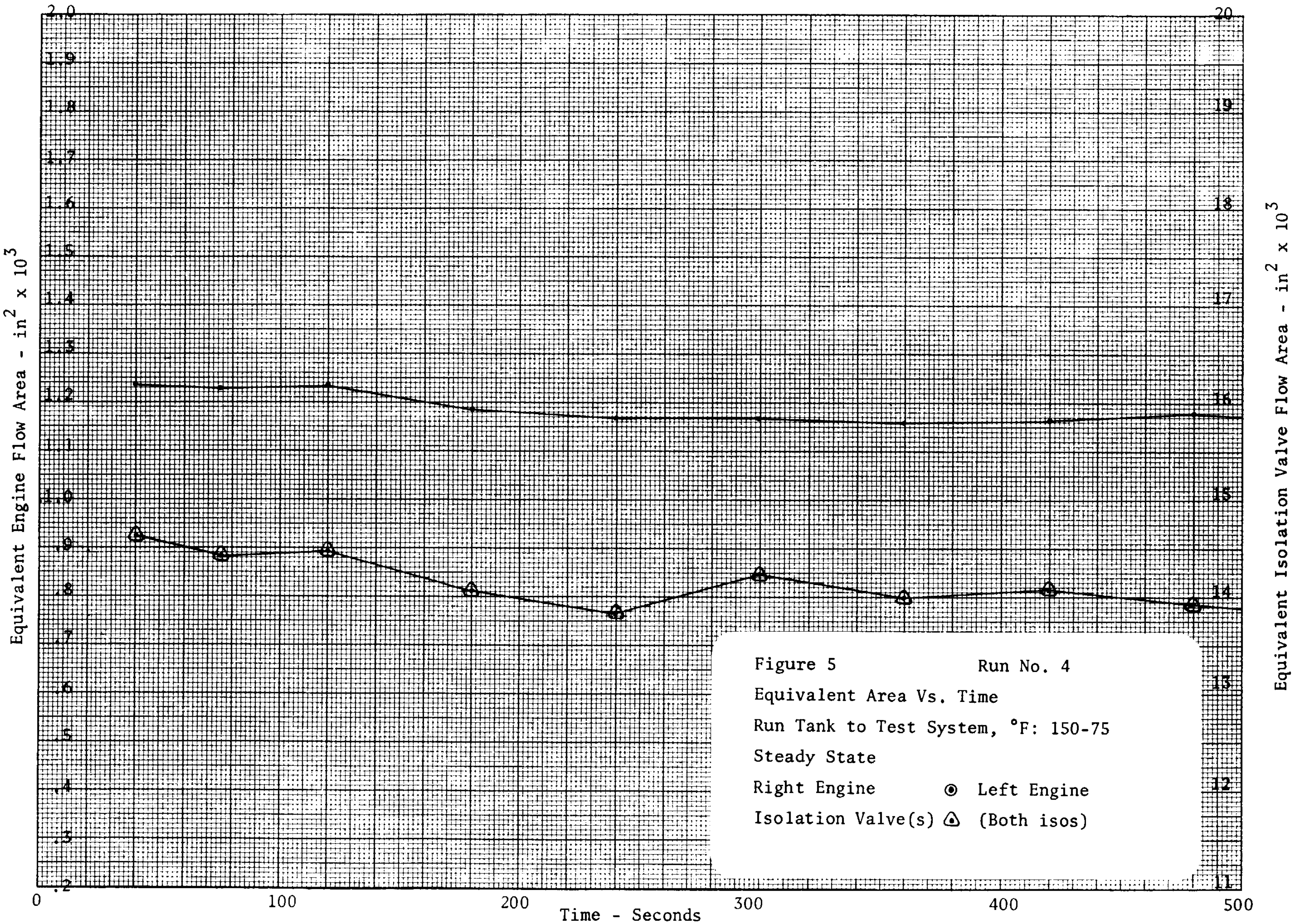


Figure 4 Run No. 3
Flow Rate Vs. Time
Run Tank to Test System, °F: 150-75
Steady State
Right Engine ⊙ Left Engine
Isolation Valve(s) △ (Both isos)


Equivalent Engine Flow Area - in^2 x 10^3
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
Equivalent Isolation Valve Flow Area - in^2 x 10^3
20
19
18
17
16
15
14
13
12
11
0
100
200
300
400
500
Time - Seconds
Figure 5
Run No. 4
Equivalent Area Vs. Time
Run Tank to Test System, °F: 150-75
Steady State
Right Engine
Left Engine
Isolation Valve(s)
(Both isos)

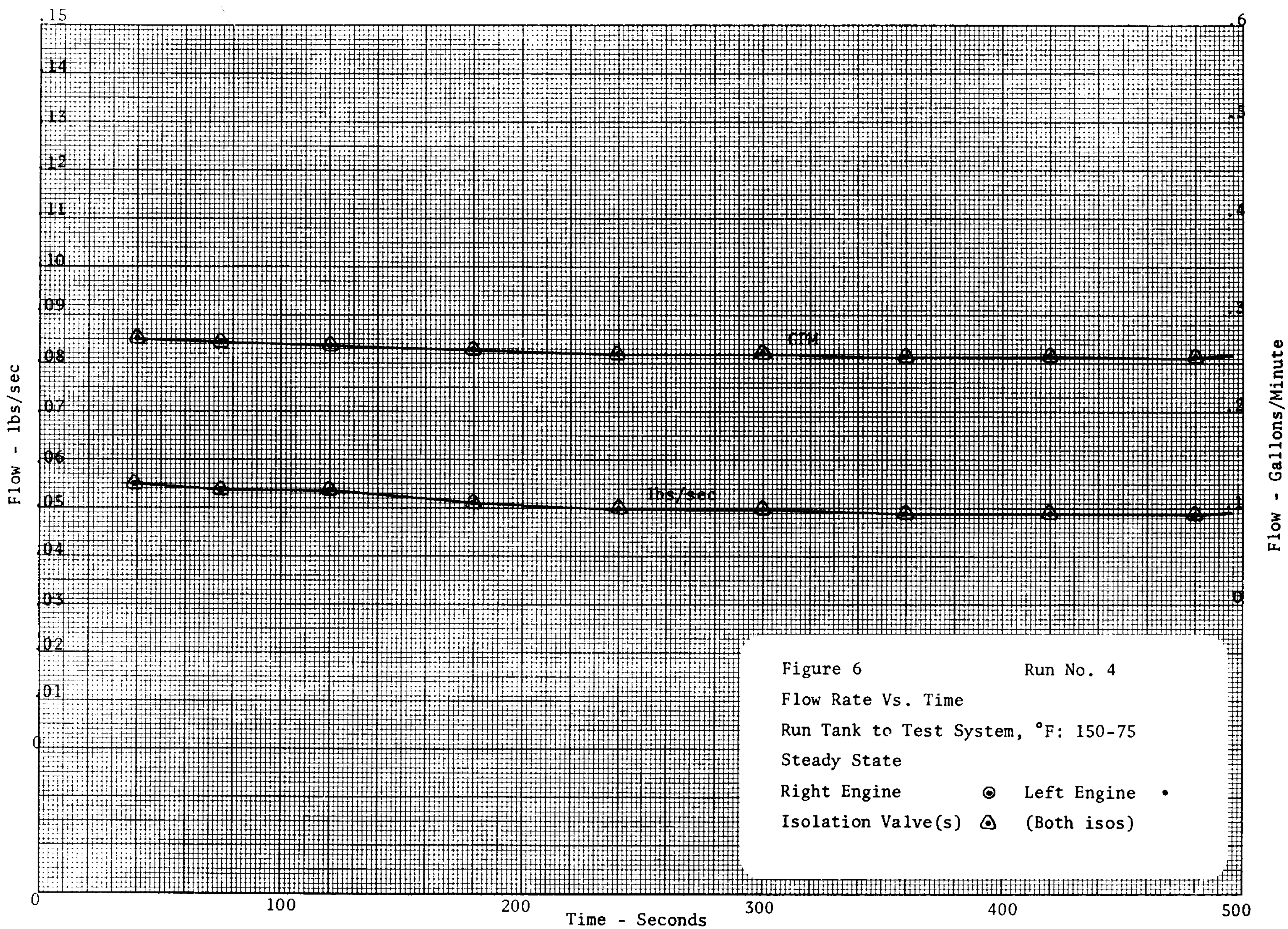


Figure 6 Run No. 4

Flow Rate Vs. Time

Run Tank to Test System, °F: 150-75

Steady State

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Both isos)

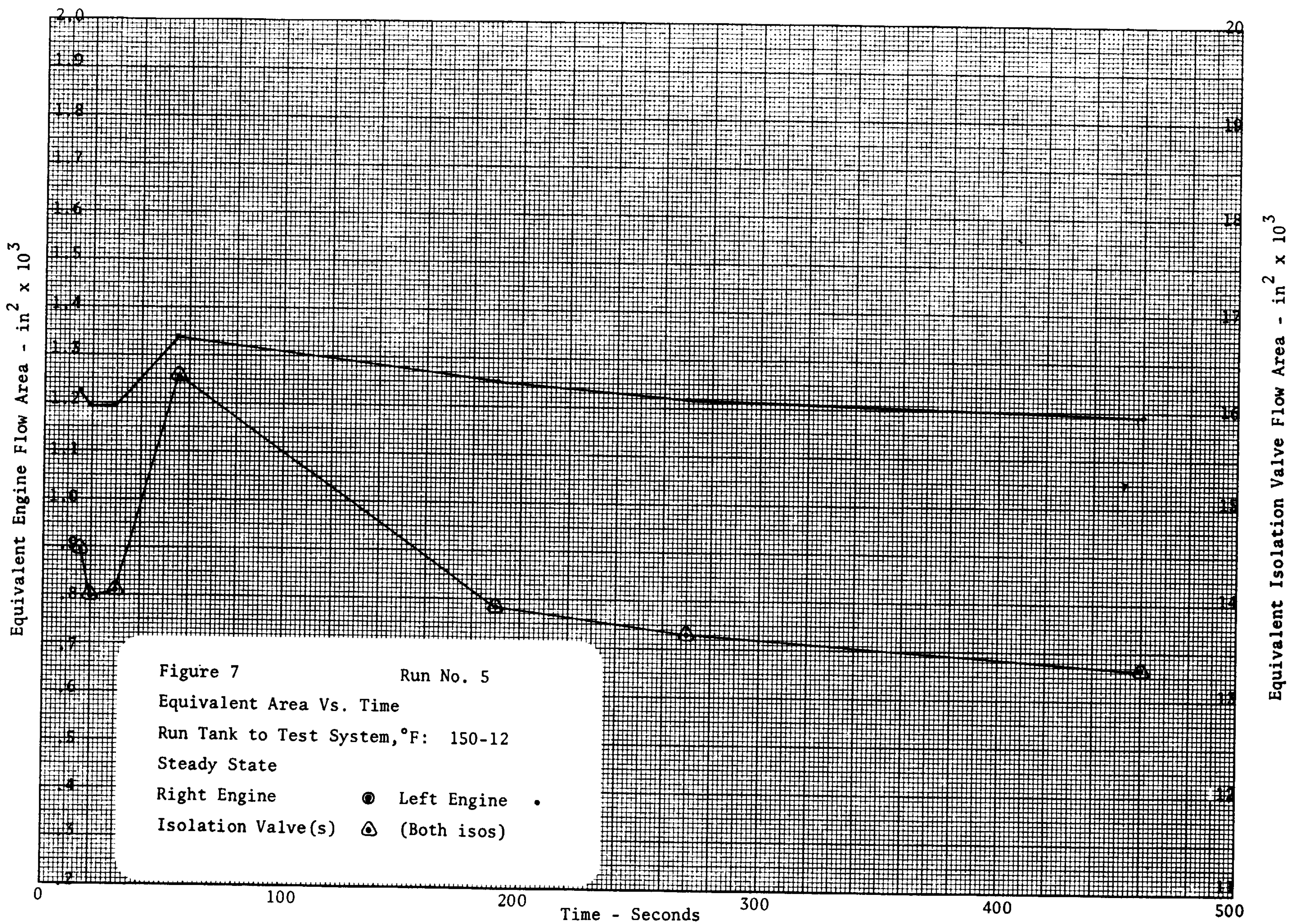
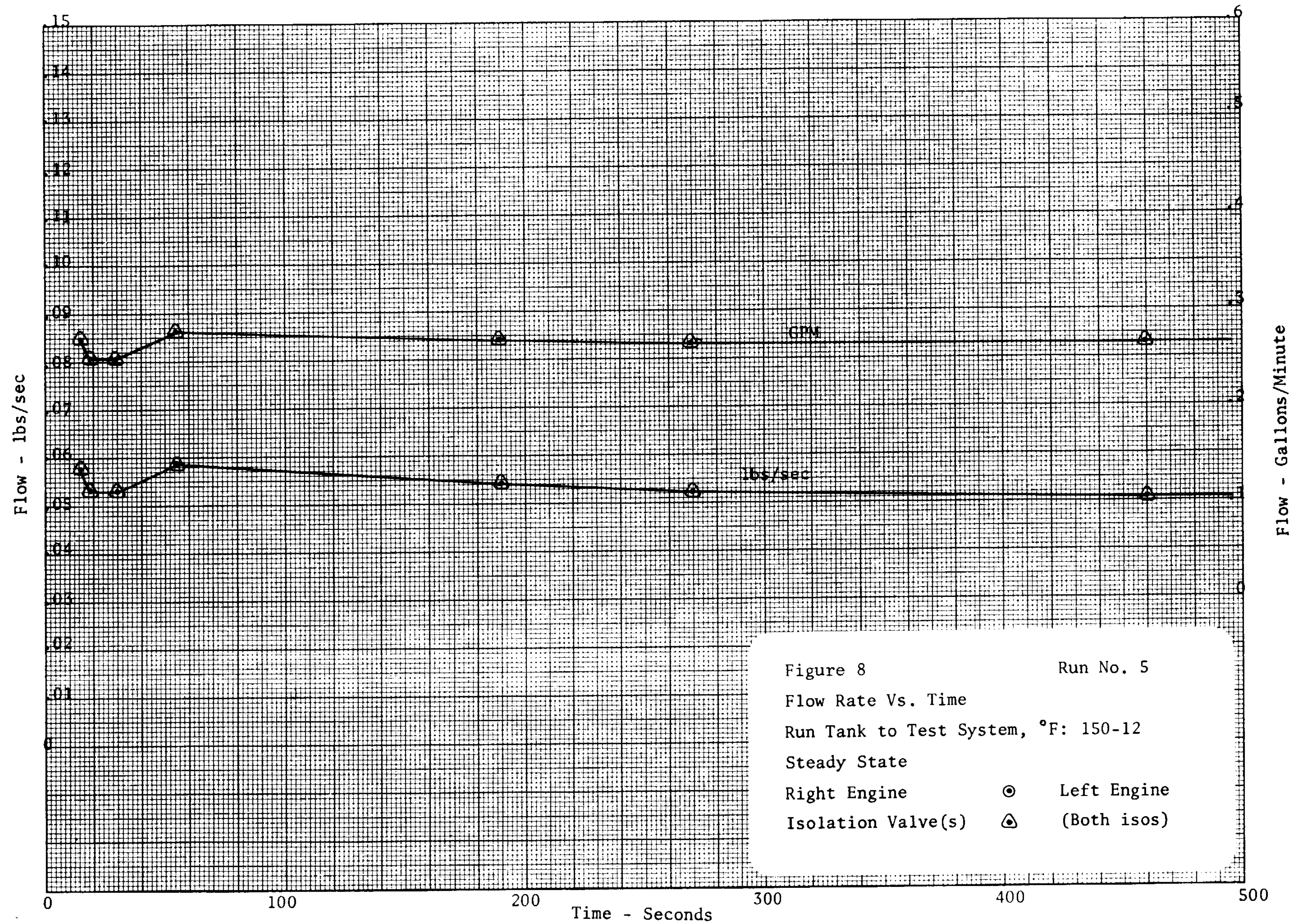


Figure 7 Run No. 5
Equivalent Area Vs. Time
Run Tank to Test System, °F: 150-12
Steady State
Right Engine ◉ Left Engine •
Isolation Valve(s) △ (Both isos)



Flow - lbs/sec
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
Flow - Gallons/Minute
.6
.5
.4
.3
.2
.1
0
GPM
lbs/sec
0
100
200
300
400
500
Time - Seconds
Figure 8
Run No. 5
Flow Rate Vs. Time
Run Tank to Test System, °F: 150-12
Steady State
Right Engine
Left Engine
Isolation Valve(s)
(Both isos)

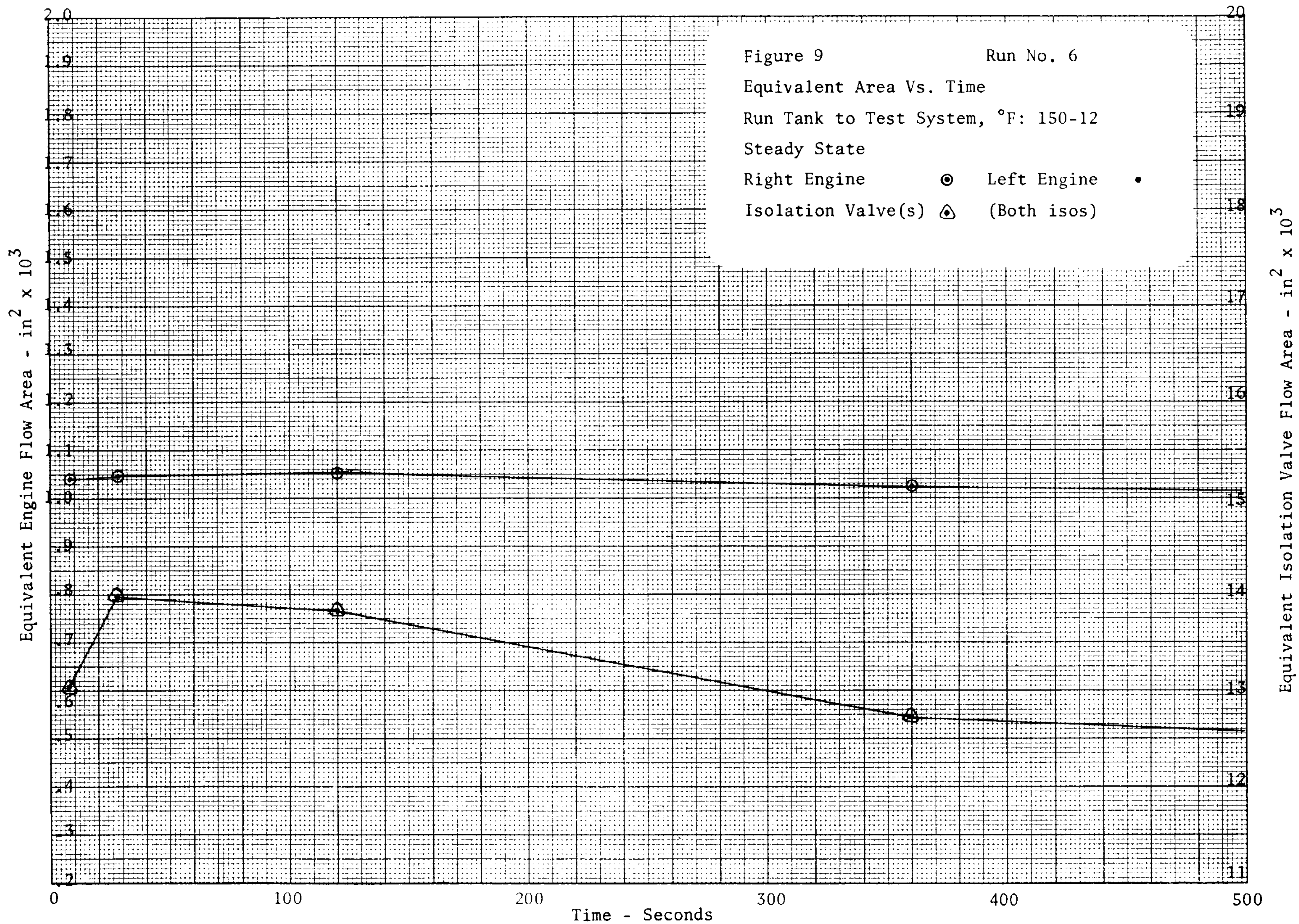


Figure 9
Run No. 6
Equivalent Area Vs. Time
Run Tank to Test System, °F: 150-12
Steady State
Right Engine
Left Engine
Isolation Valve(s)
(Both isos)
Equivalent Engine Flow Area - in2 x 103
Equivalent Isolation Valve Flow Area - in2 x 103
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
20
19
18
17
16
15
14
13
12
11

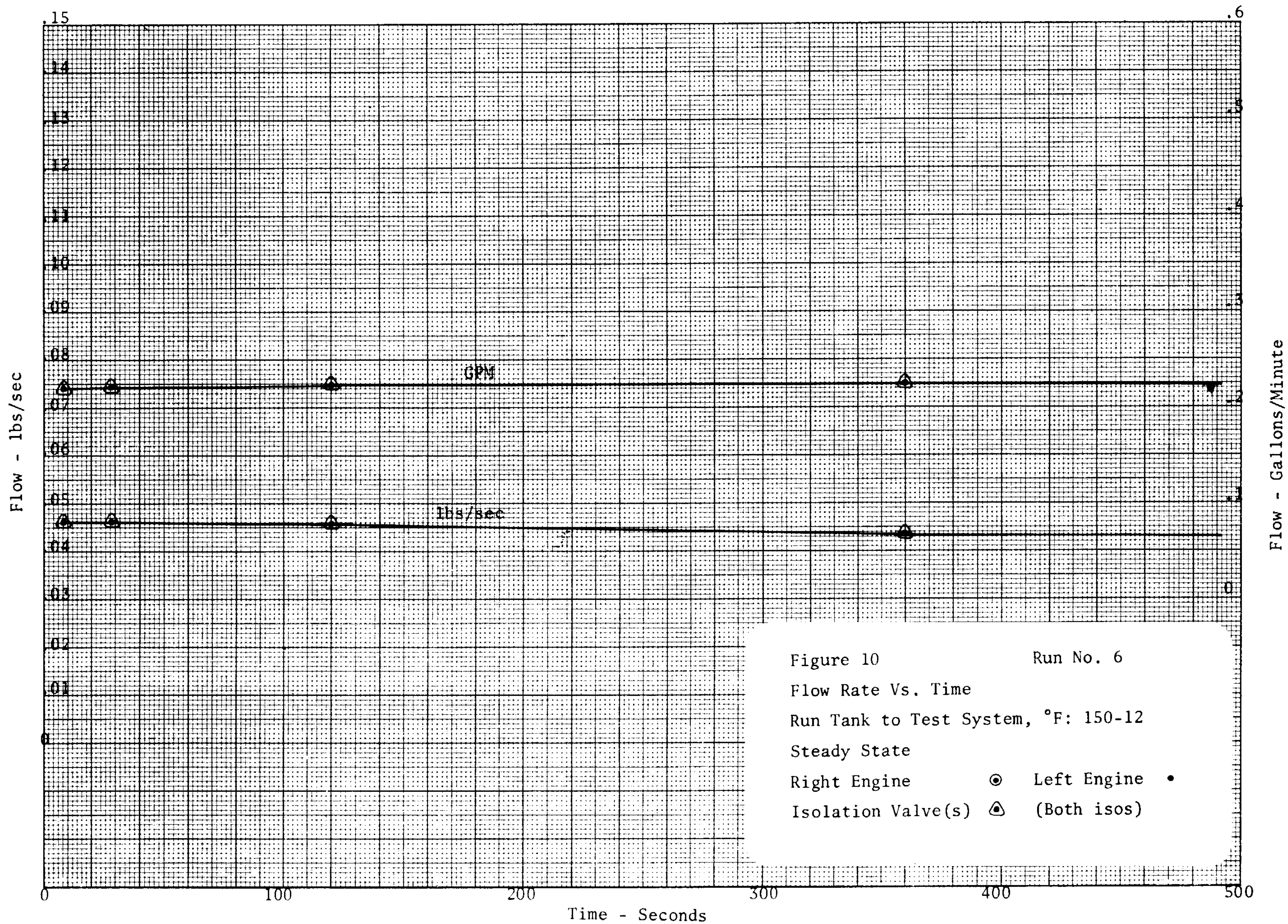
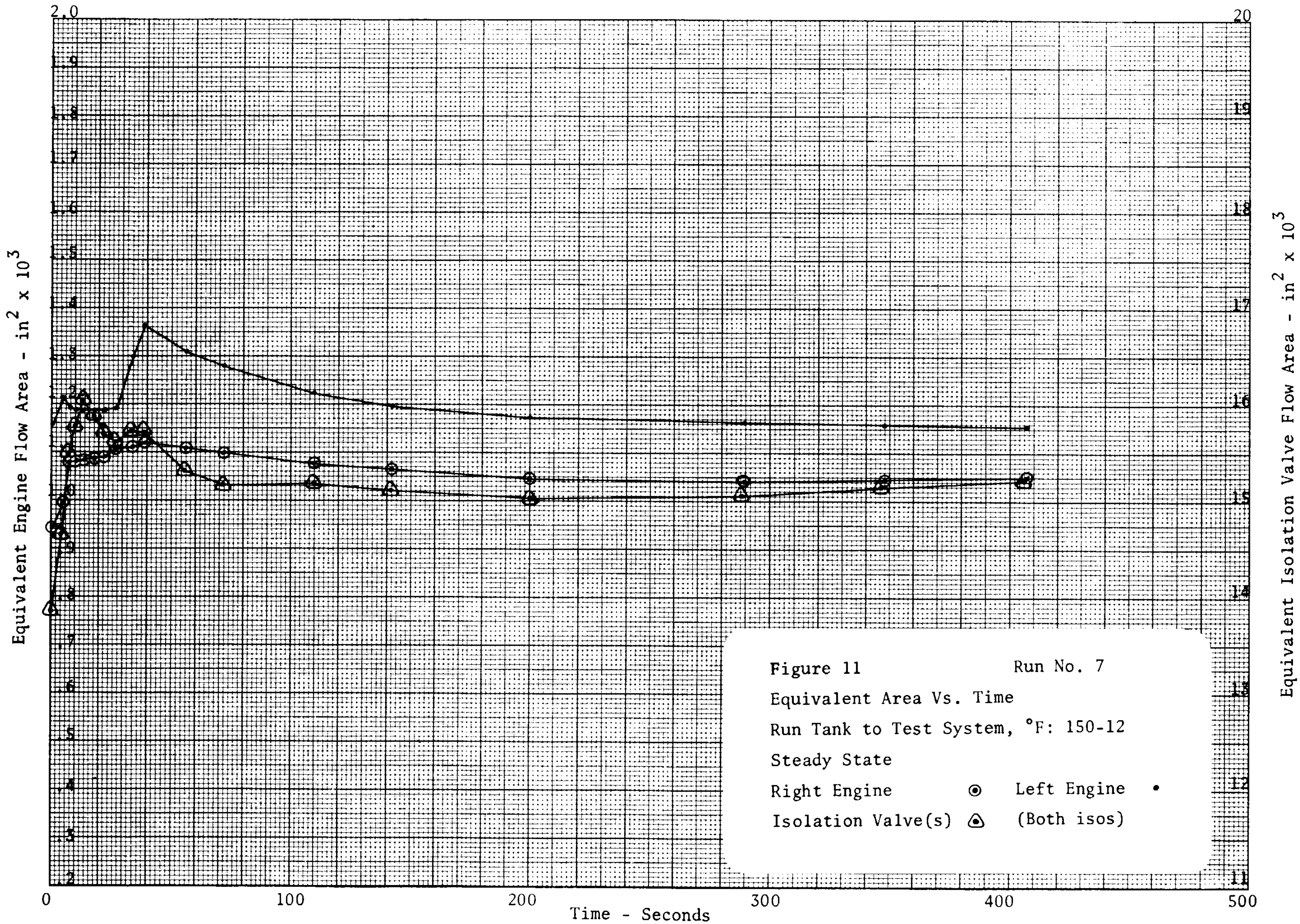


Figure 10 Run No. 6

Flow Rate Vs. Time

Run Tank to Test System, °F: 150-12

Steady State



Equivalent Engine Flow Area - in^2 x 10^3
Equivalent Isolation Valve Flow Area - in^2 x 10^3
Time - Seconds
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
20
19
18
17
16
15
14
13
12
11
0
100
200
300
400
500
Figure 11
Run No. 7
Equivalent Area Vs. Time
Run Tank to Test System, °F: 150-12
Steady State
Right Engine
Left Engine
Isolation Valve(s)
(Both isos)

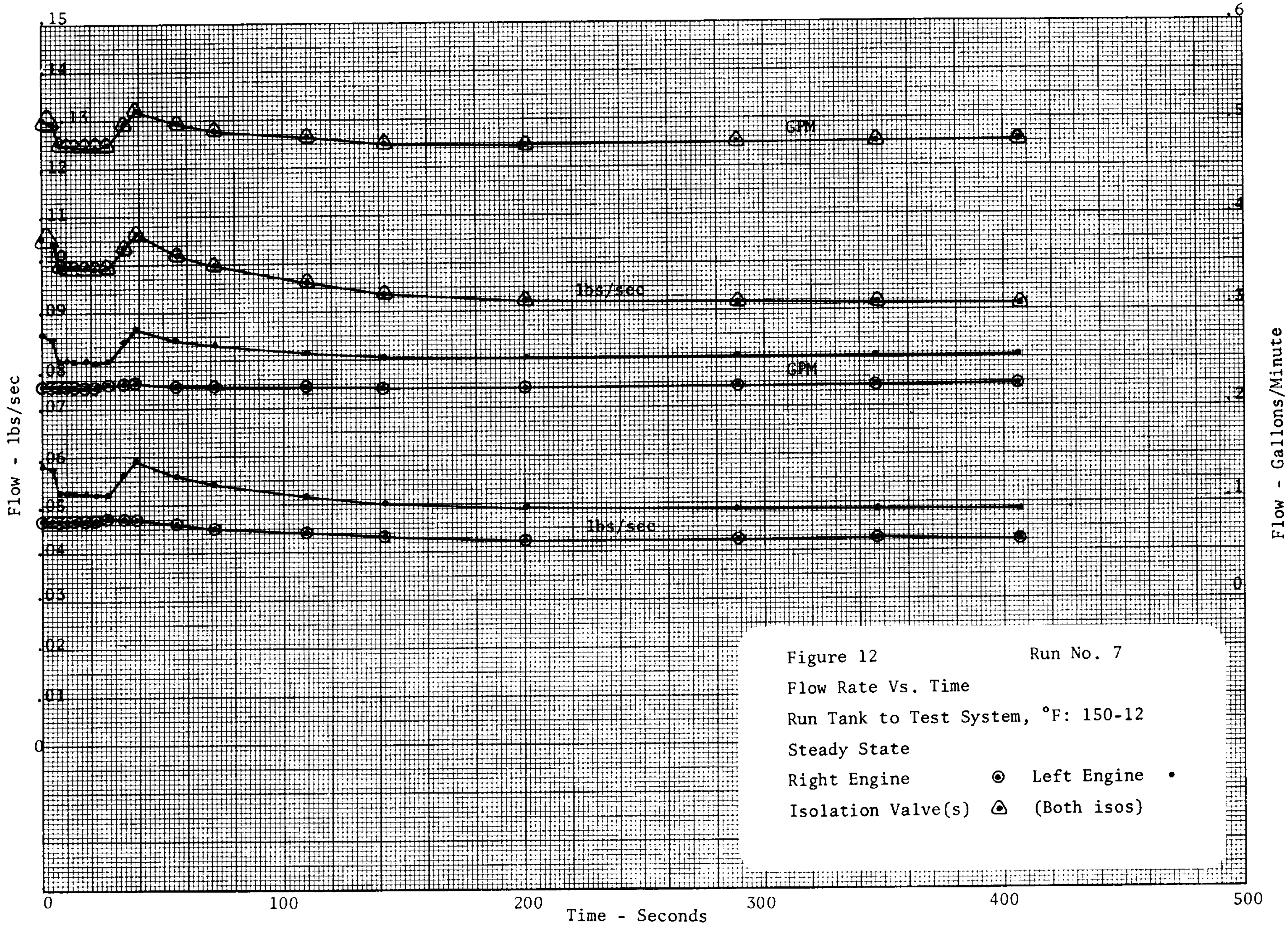


Figure 12 Run No. 7

Flow Rate Vs. Time

Run Tank to Test System, °F: 150-12

Steady State

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Both isos)

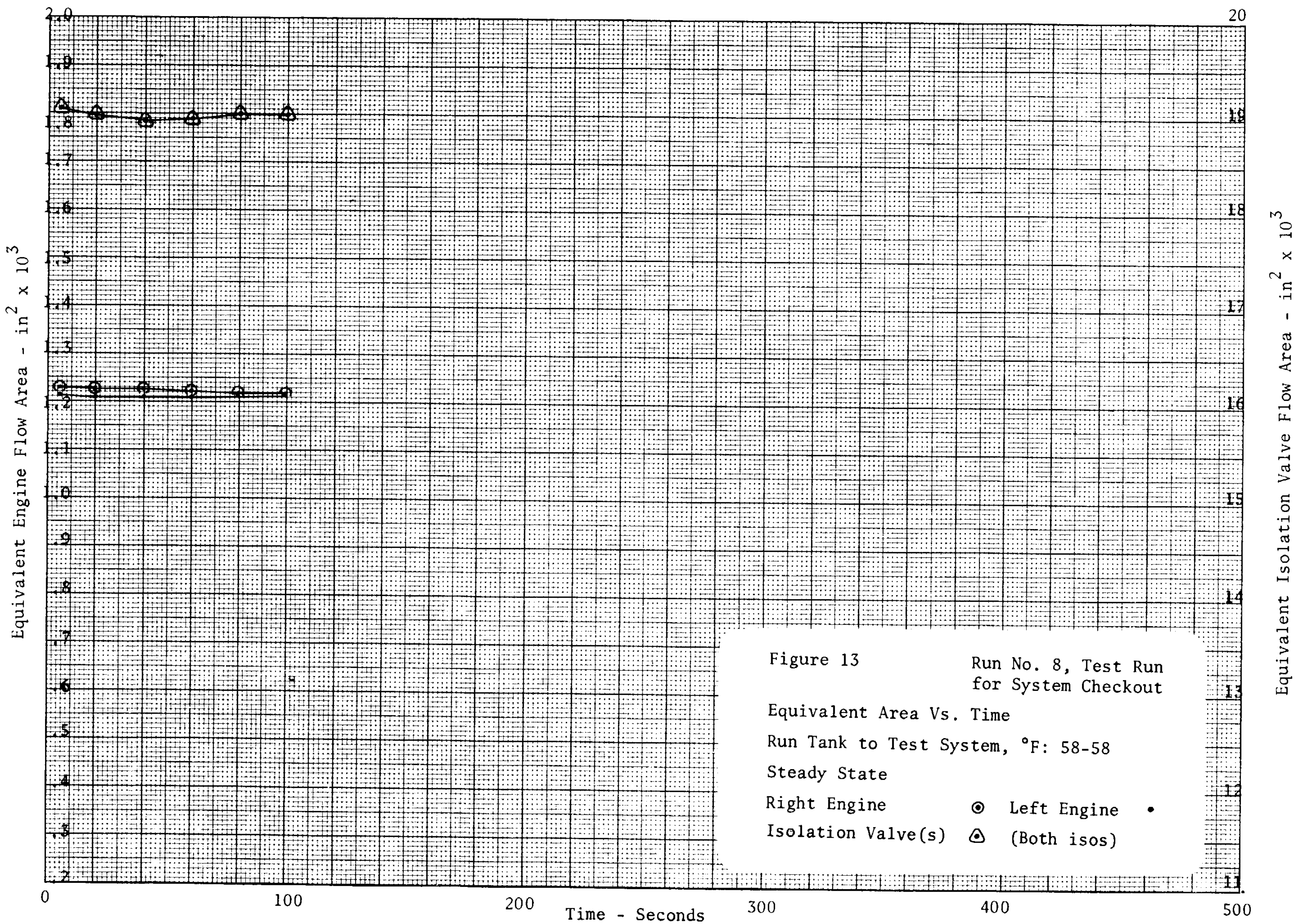


Figure 13
Run No. 8, Test Run for System Checkout
Equivalent Area Vs. Time
Run Tank to Test System, °F: 58-58
Steady State
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Both isos)
Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
20
19
18
17
16
15
14
13
12
11

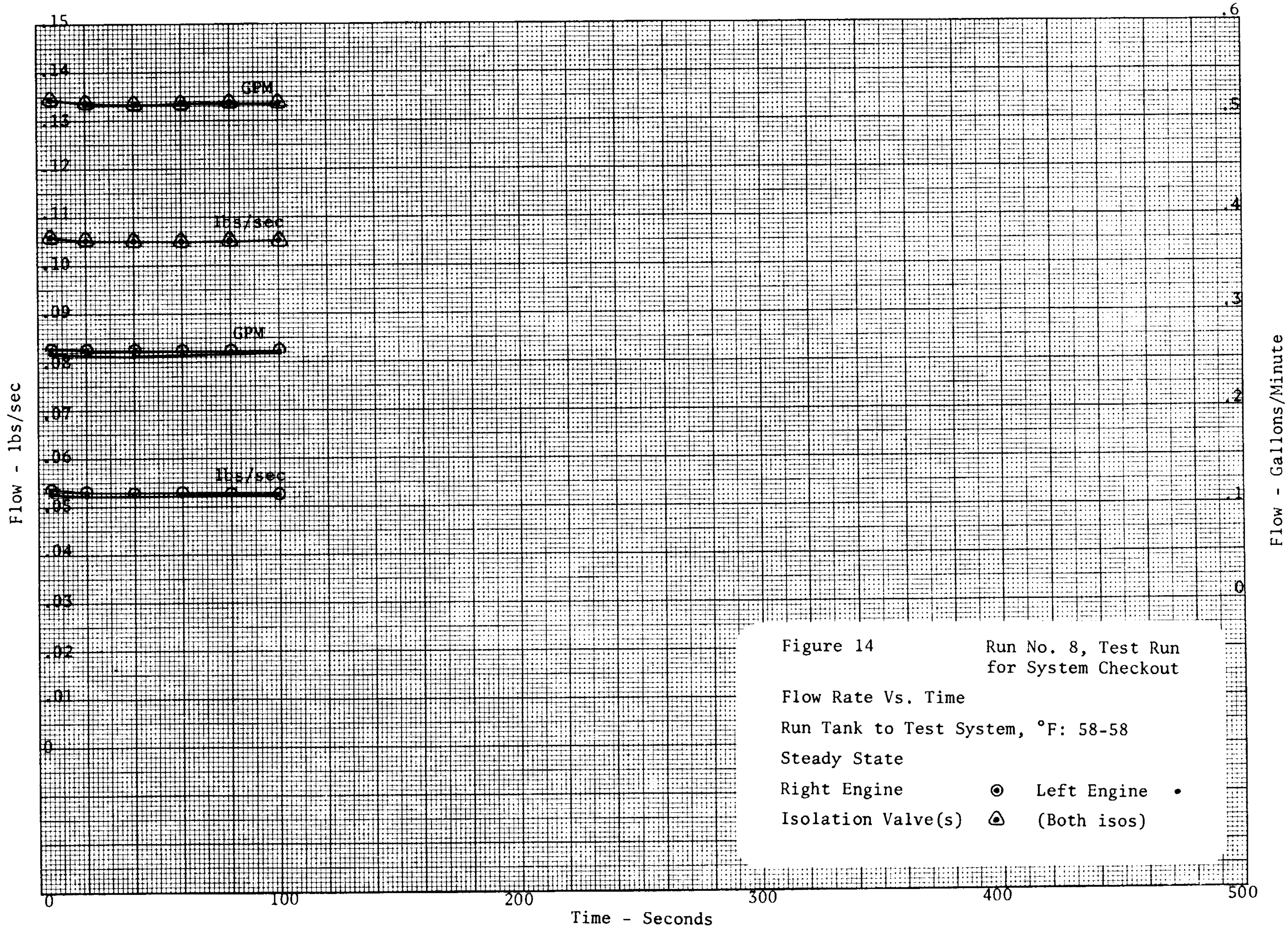


Figure 14

Run No. 8, Test Run for System Checkout

Flow Rate Vs. Time

Run Tank to Test System, °F: 58-58

Steady State

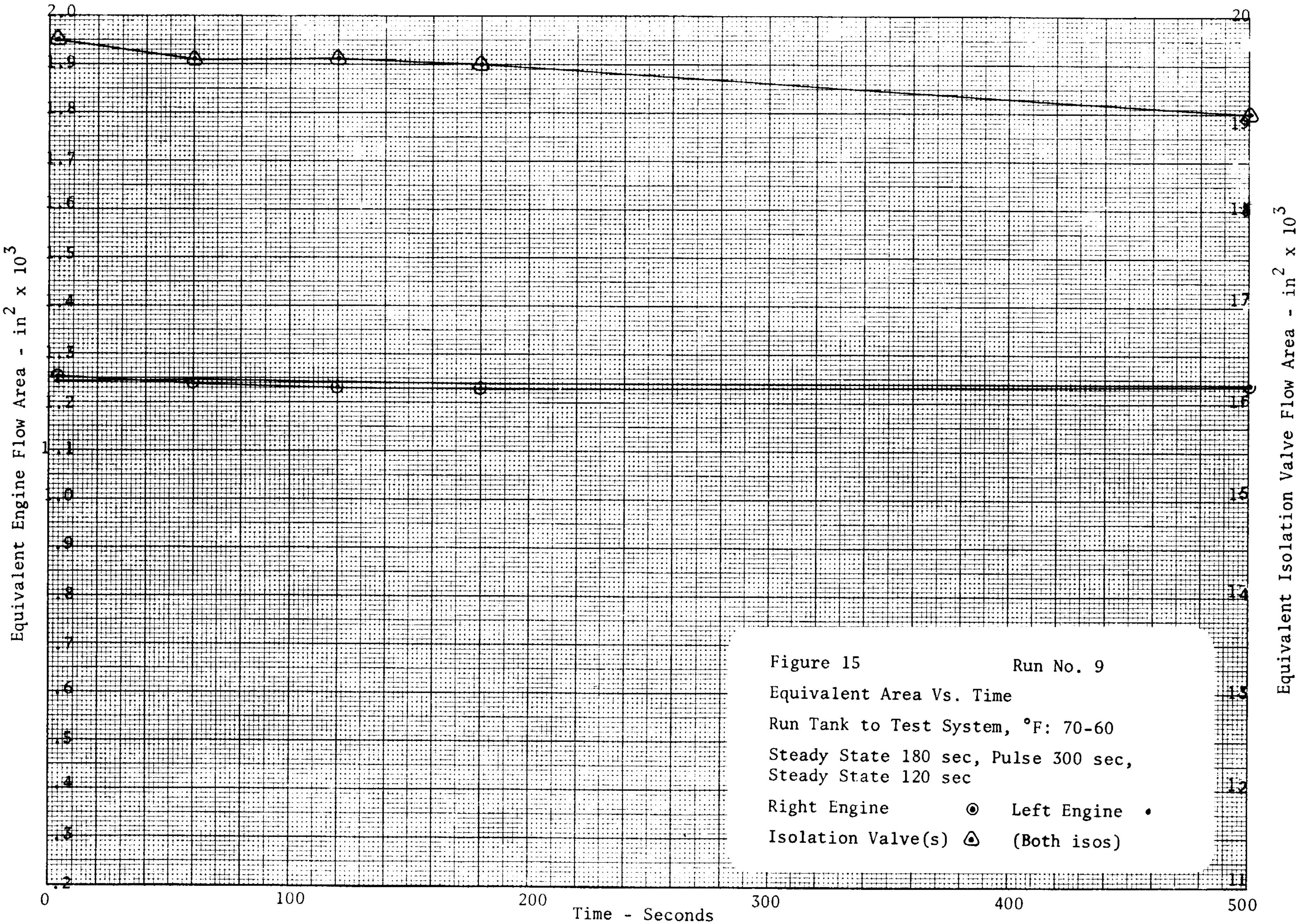


Figure 15 Run No. 9

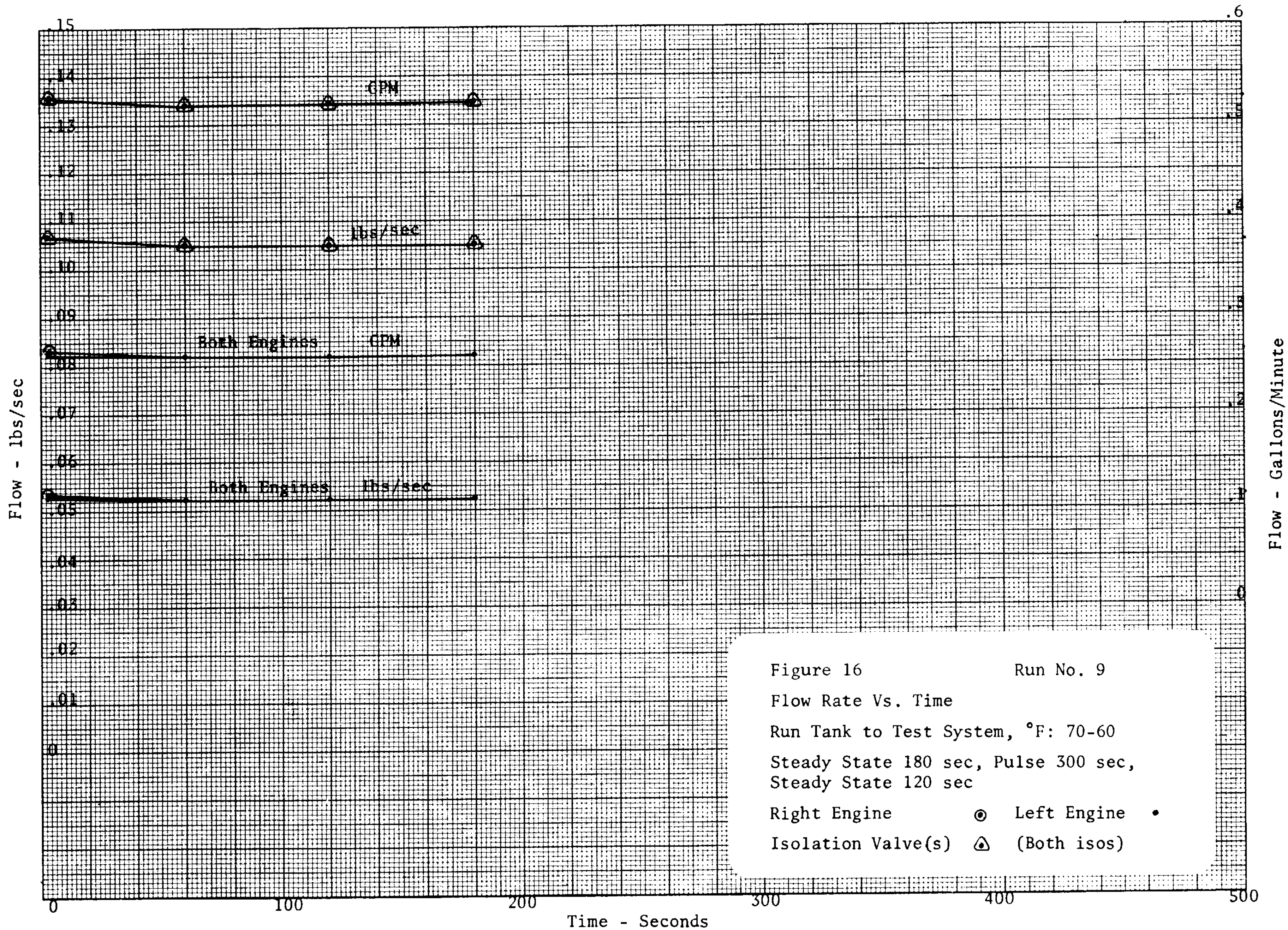
Equivalent Area Vs. Time

Run Tank to Test System, °F: 70-60

Steady State 180 sec, Pulse 300 sec,
Steady State 120 sec

Right Engine ◉ Left Engine •

Isolation Valve(s) △ (Both isos)



.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
.6
.5
.4
.3
.2
.1
0
0
100
200
300
400
500
Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
GPM
lbs/sec
Both Engines
GPM
Both Engines
lbs/sec
Figure 16
Run No. 9
Flow Rate Vs. Time
Run Tank to Test System, °F: 70-60
Steady State 180 sec, Pulse 300 sec,
Steady State 120 sec
Right Engine
Left Engine
Isolation Valve(s)
(Both isos)

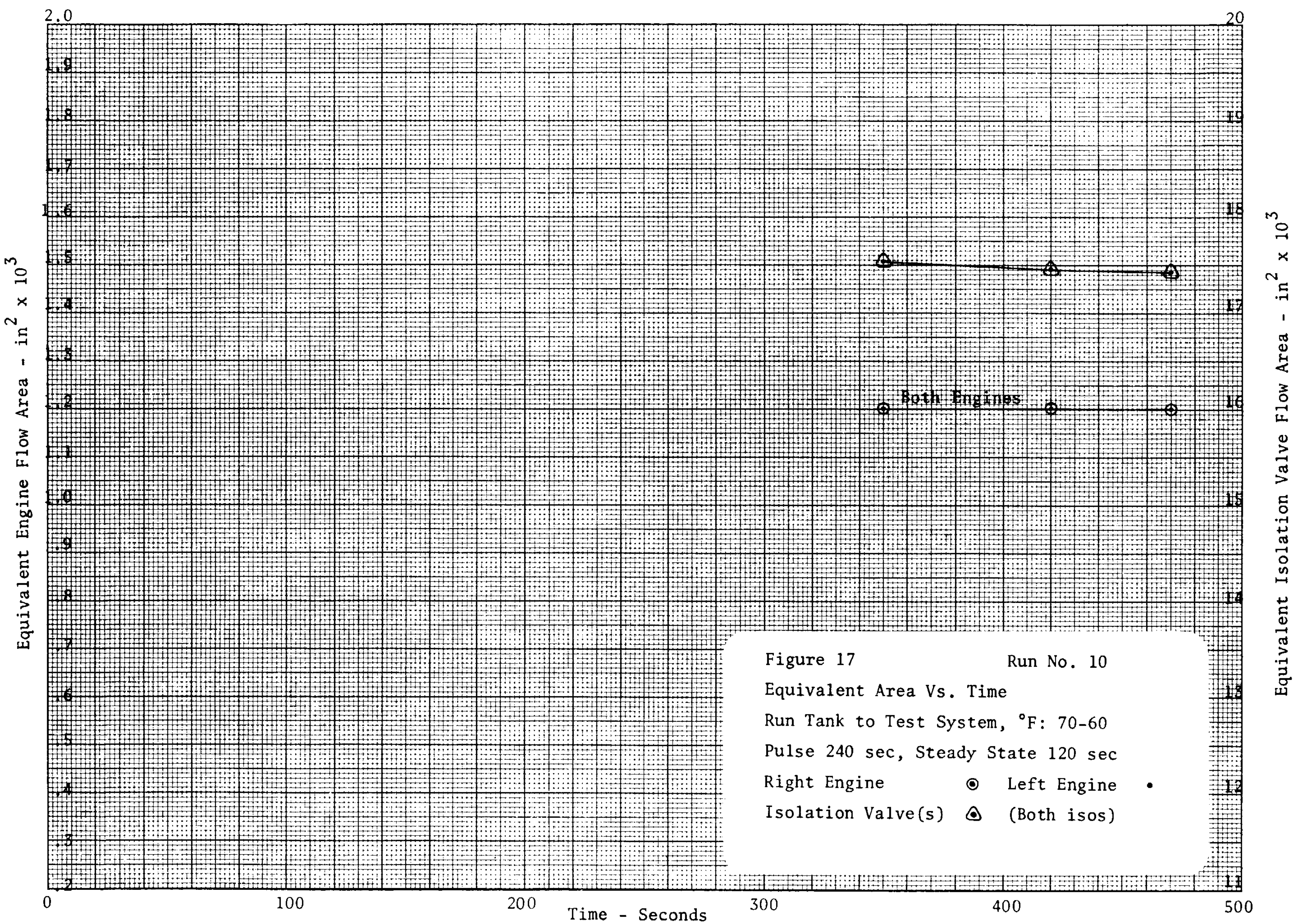


Figure 17 Run No. 10

Equivalent Area Vs. Time

Run Tank to Test System, °F: 70-60

Pulse 240 sec, Steady State 120 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Both isos)

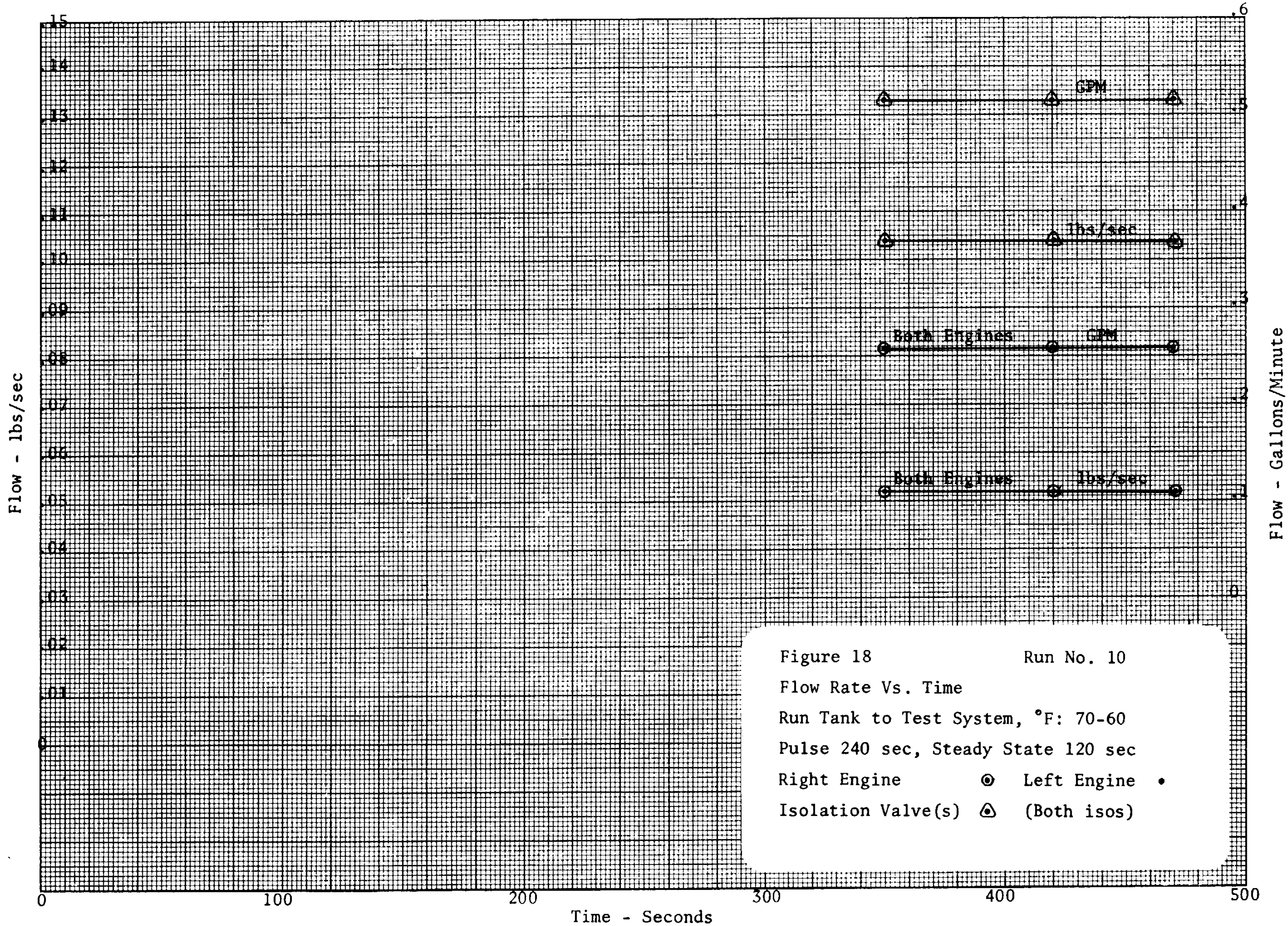


Figure 18 Run No. 10

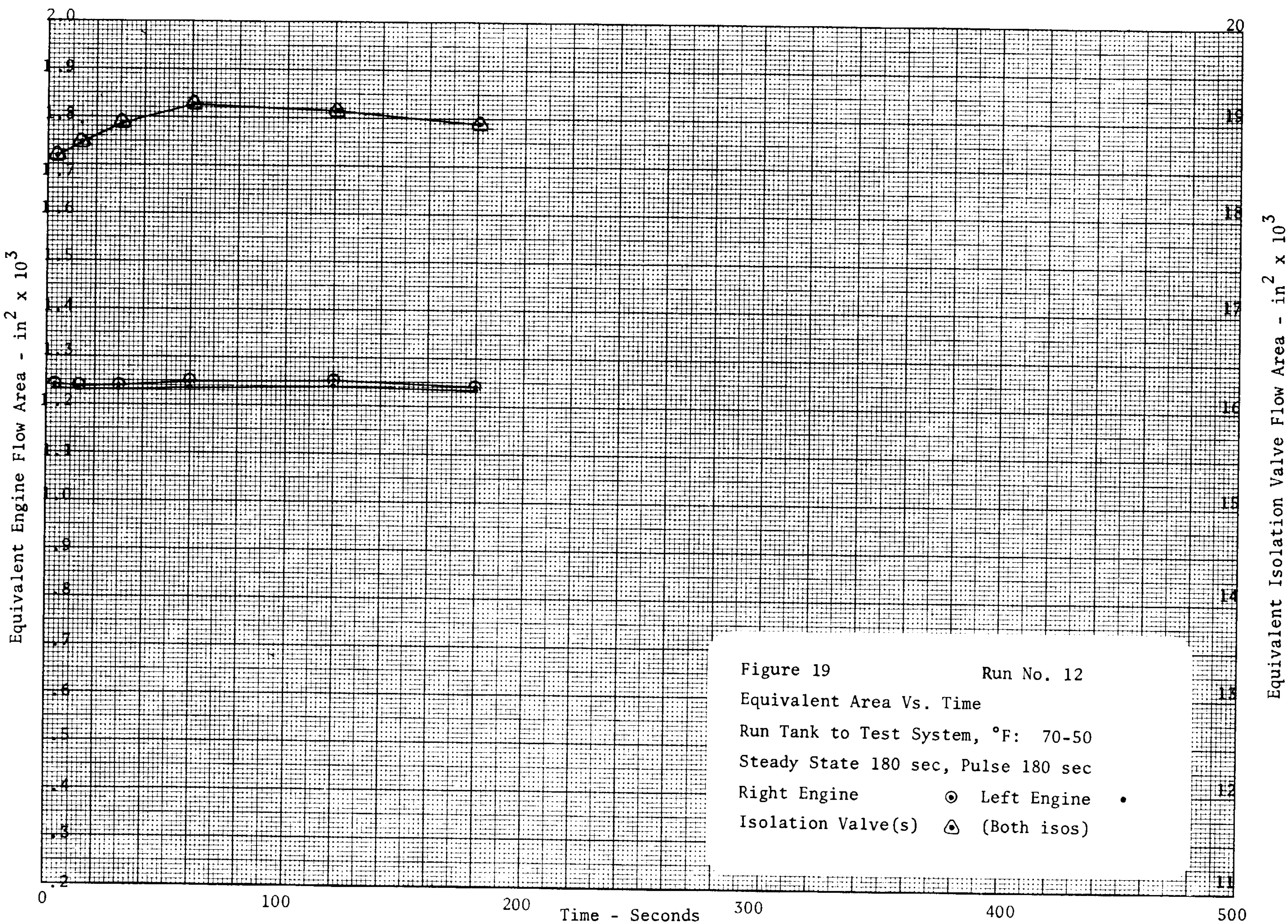
Flow Rate Vs. Time

Run Tank to Test System, °F: 70-60

Pulse 240 sec, Steady State 120 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Both isos)



2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
Equivalent Engine Flow Area - in^2 x 10^3
20
19
18
17
16
15
14
13
12
11
Equivalent Isolation Valve Flow Area - in^2 x 10^3
0
100
200
300
400
500
Time - Seconds
Figure 19
Run No. 12
Equivalent Area Vs. Time
Run Tank to Test System, °F: 70-50
Steady State 180 sec, Pulse 180 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) (Both isos)

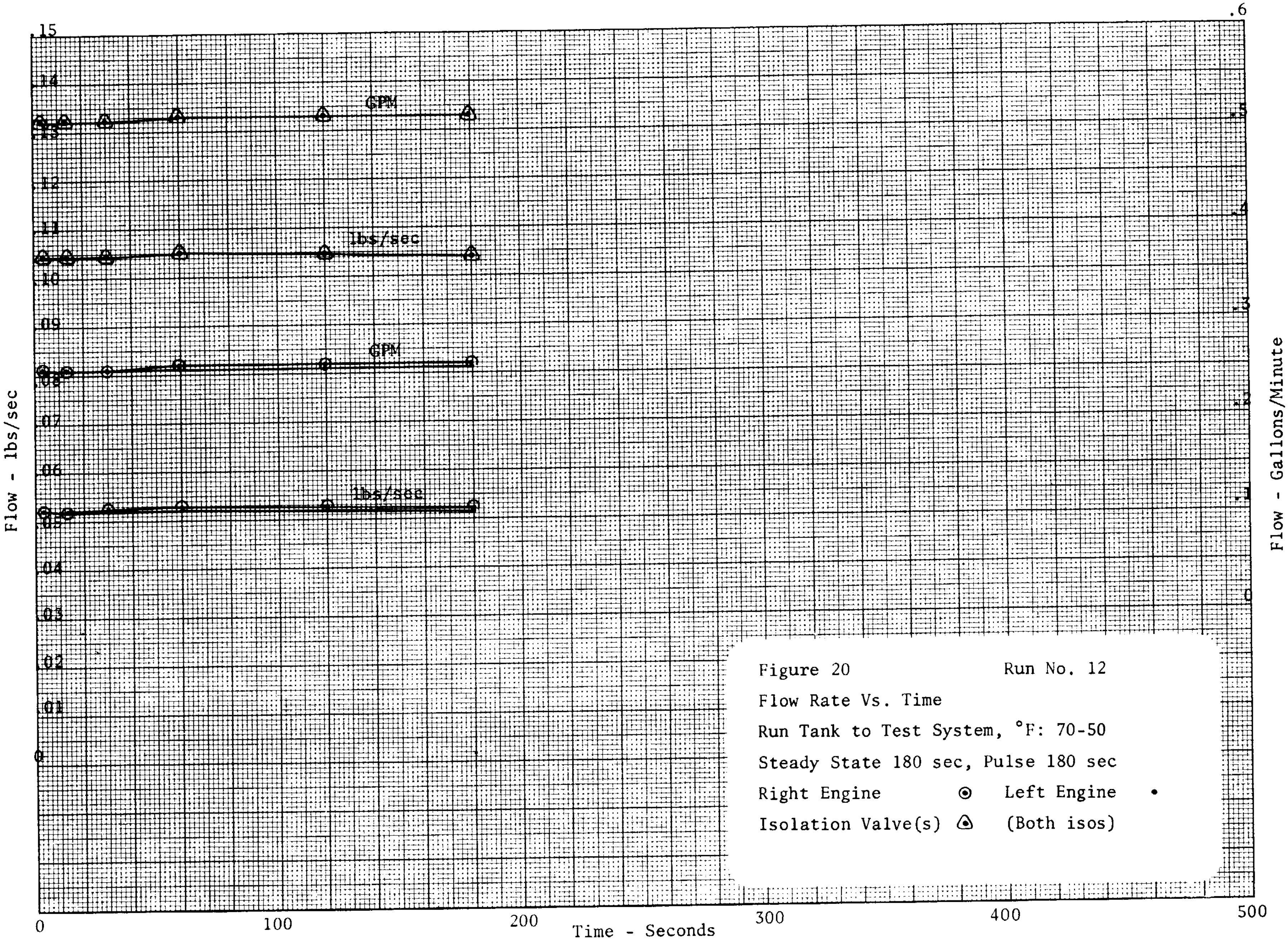


Figure 20 Run No. 12

Flow Rate Vs. Time

Run Tank to Test System, °F: 70-50

Steady State 180 sec, Pulse 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Both isos)

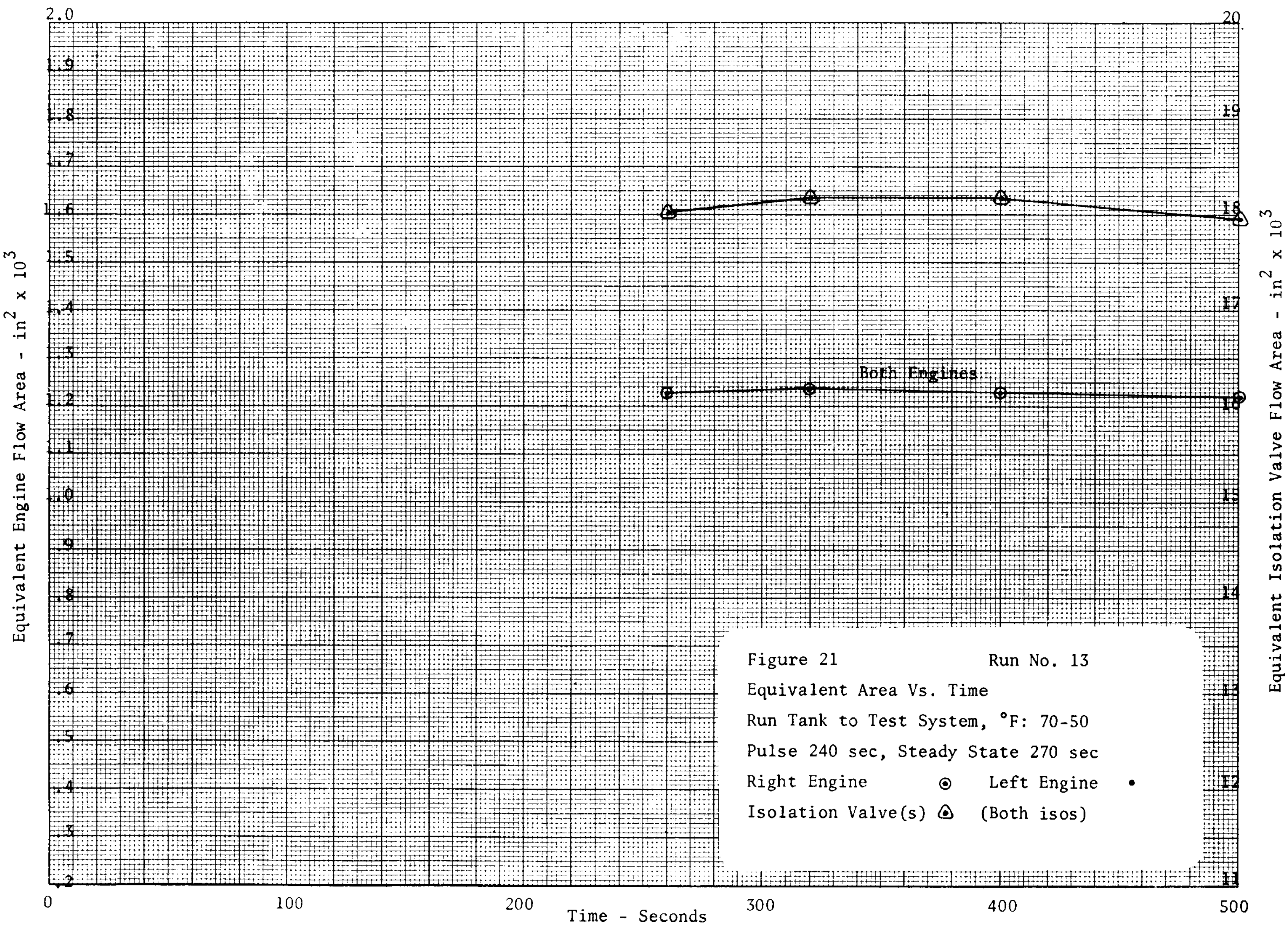


Figure 21 Run No. 13

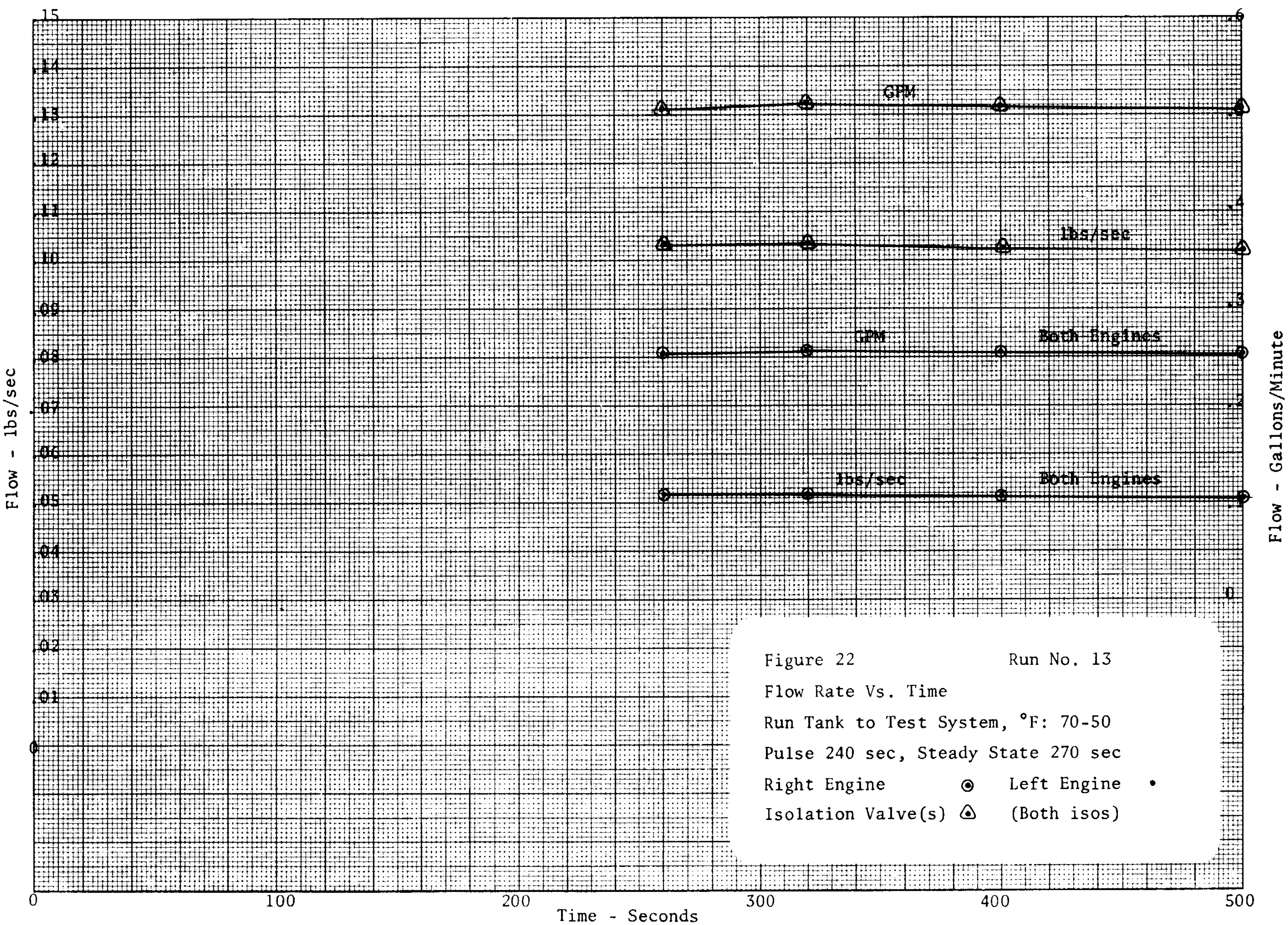
Equivalent Area Vs. Time

Run Tank to Test System, °F: 70-50

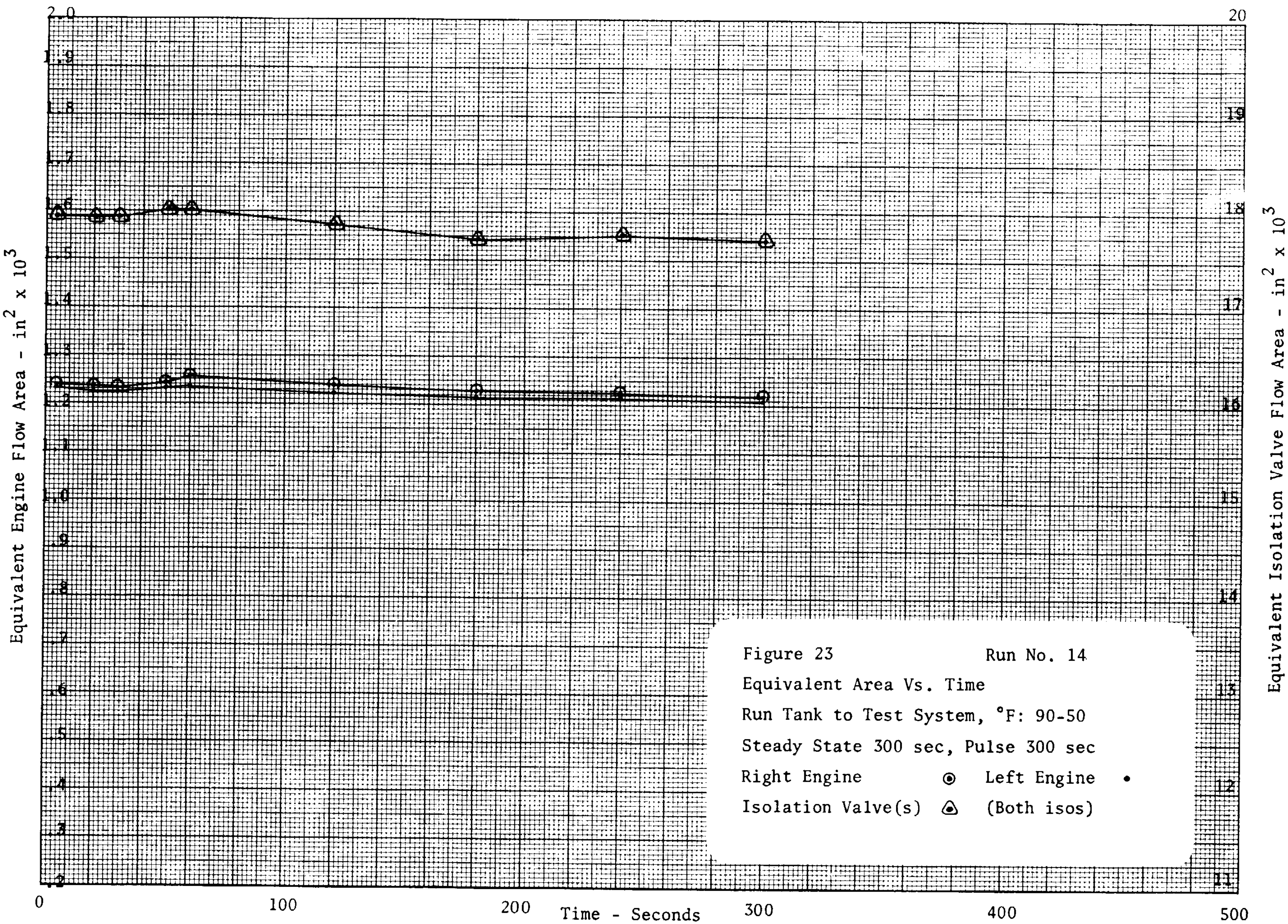
Pulse 240 sec, Steady State 270 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) (Both isos)



.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
Flow - lbs/sec
.6
.4
.3
.2
0
Flow - Gallons/Minute
0
100
200
300
400
500
Time - Seconds
GPM
lbs/sec
GPM
Both Engines
lbs/sec
Both Engines
Figure 22 Run No. 13
Flow Rate Vs. Time
Run Tank to Test System, °F: 70-50
Pulse 240 sec, Steady State 270 sec
Right Engine Left Engine
Isolation Valve(s) (Both isos)



2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
20
19
18
17
16
15
14
13
12
11
0
100
200
300
400
500
Equivalent Engine Flow Area - $in^2 \times 10^3$
Equivalent Isolation Valve Flow Area - $in^2 \times 10^3$
Time - Seconds
Figure 23 Run No. 14
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-50
Steady State 300 sec, Pulse 300 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) (Both isos)

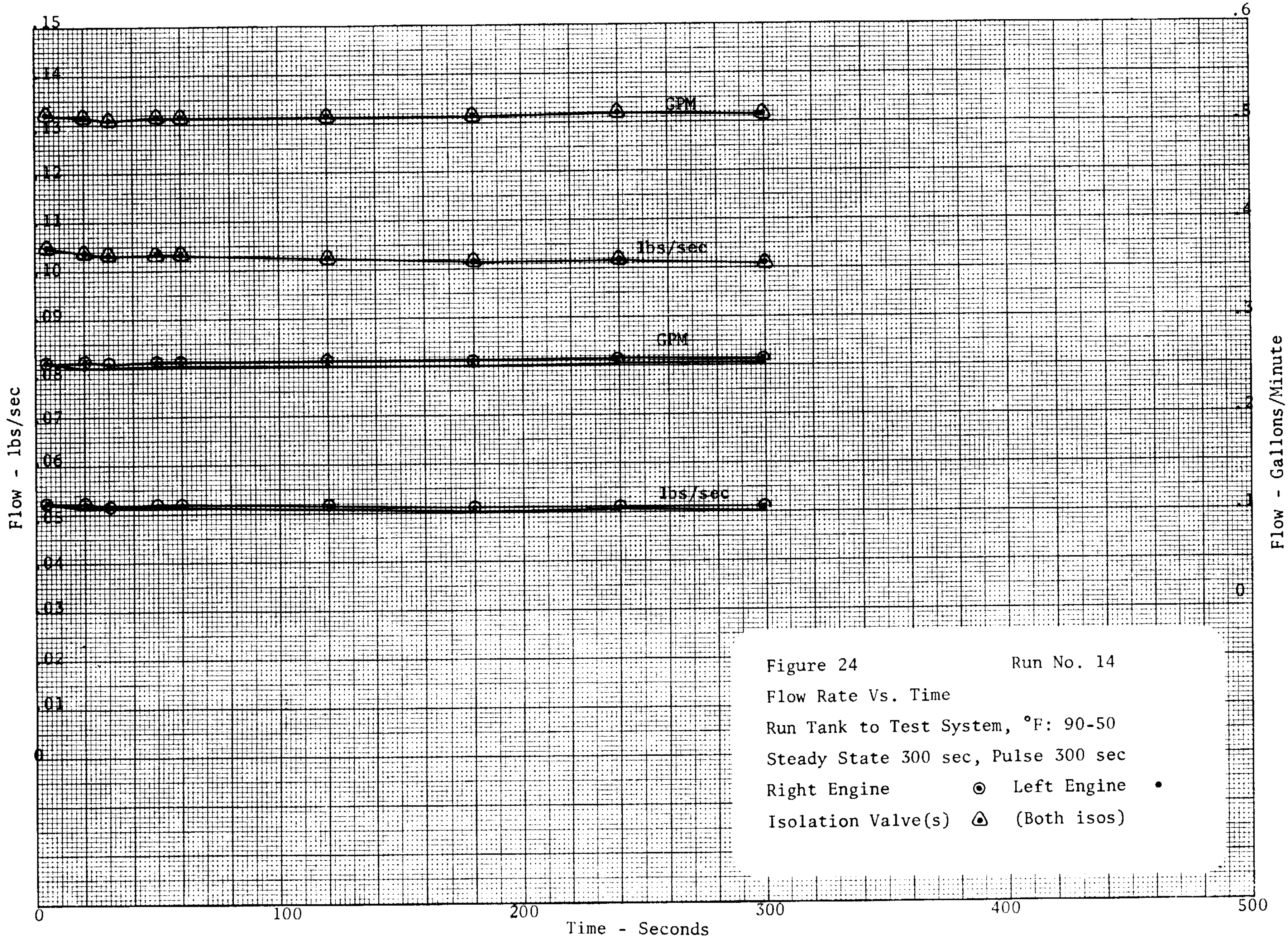


Figure 24 Run No. 14

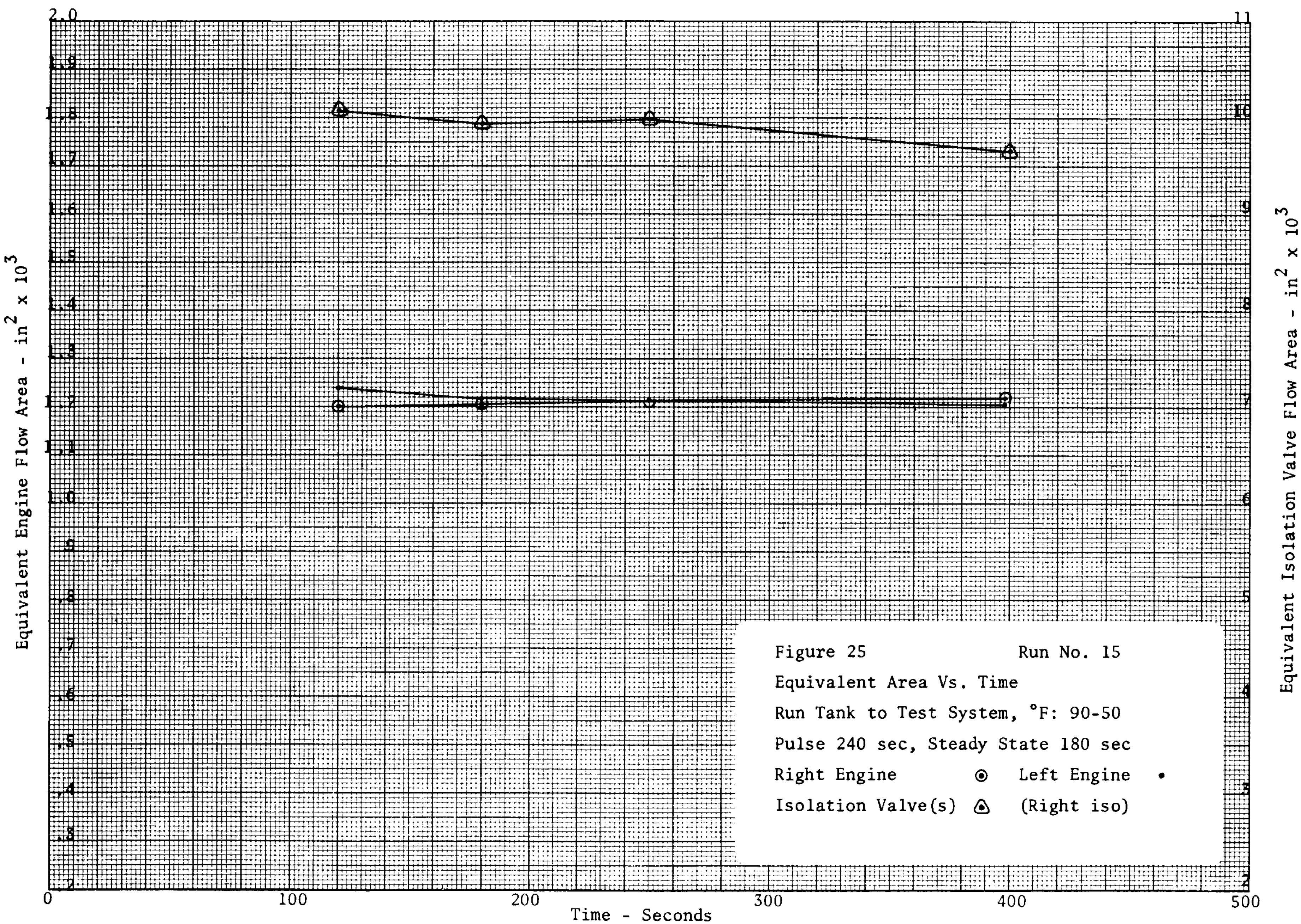
Flow Rate Vs. Time

Run Tank to Test System, °F: 90-50

Steady State 300 sec, Pulse 300 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Both isos)



Equivalent Engine Flow Area - $in^2 \times 10^3$
Equivalent Isolation Valve Flow Area - $in^2 \times 10^3$
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2
Figure 25
Run No. 15
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-50
Pulse 240 sec, Steady State 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)

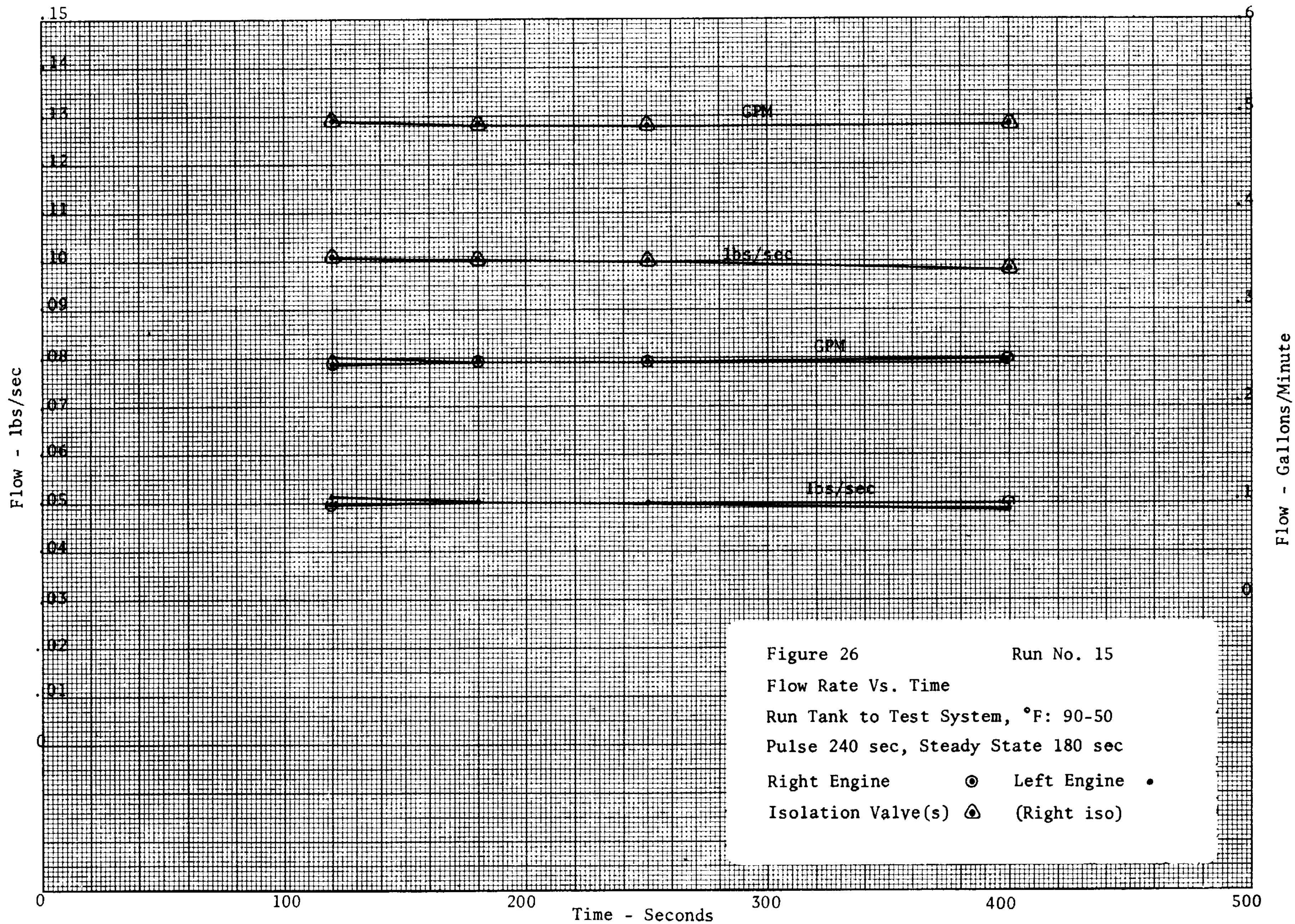


Figure 26 Run No. 15

Flow Rate Vs. Time

Run Tank to Test System, °F: 90-50

Pulse 240 sec, Steady State 180 sec

Right Engine ◉ Left Engine •

Isolation Valve(s) △ (Right iso)

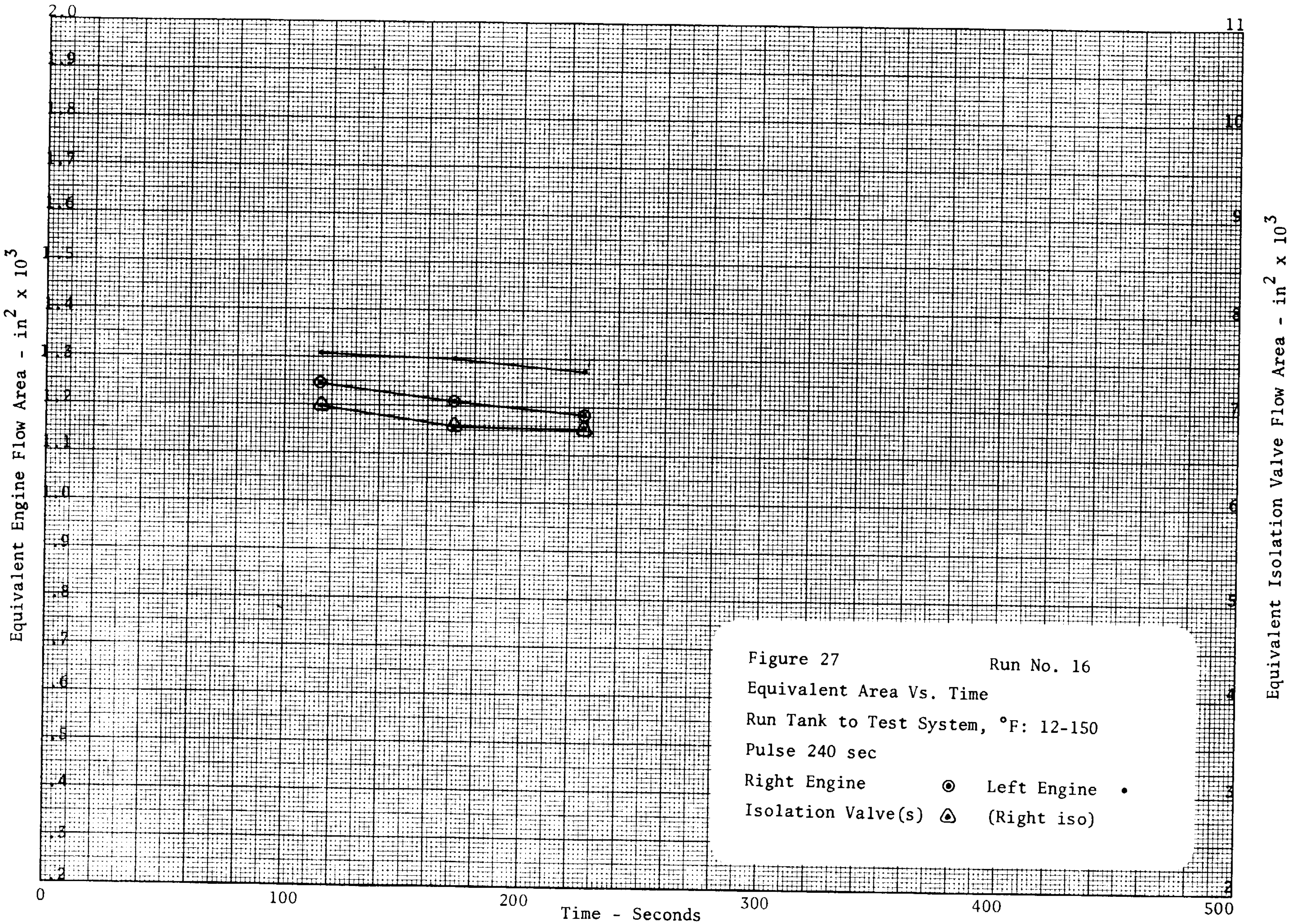


Figure 27
Run No. 16
Equivalent Area Vs. Time
Run Tank to Test System, °F: 12-150
Pulse 240 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Right iso)
Equivalent Engine Flow Area - in^2 x 10^3
Equivalent Isolation Valve Flow Area - in^2 x 10^3
Time - Seconds
0
100
200
300
400
500
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2
3
4
5
6
7
8
9
10
11

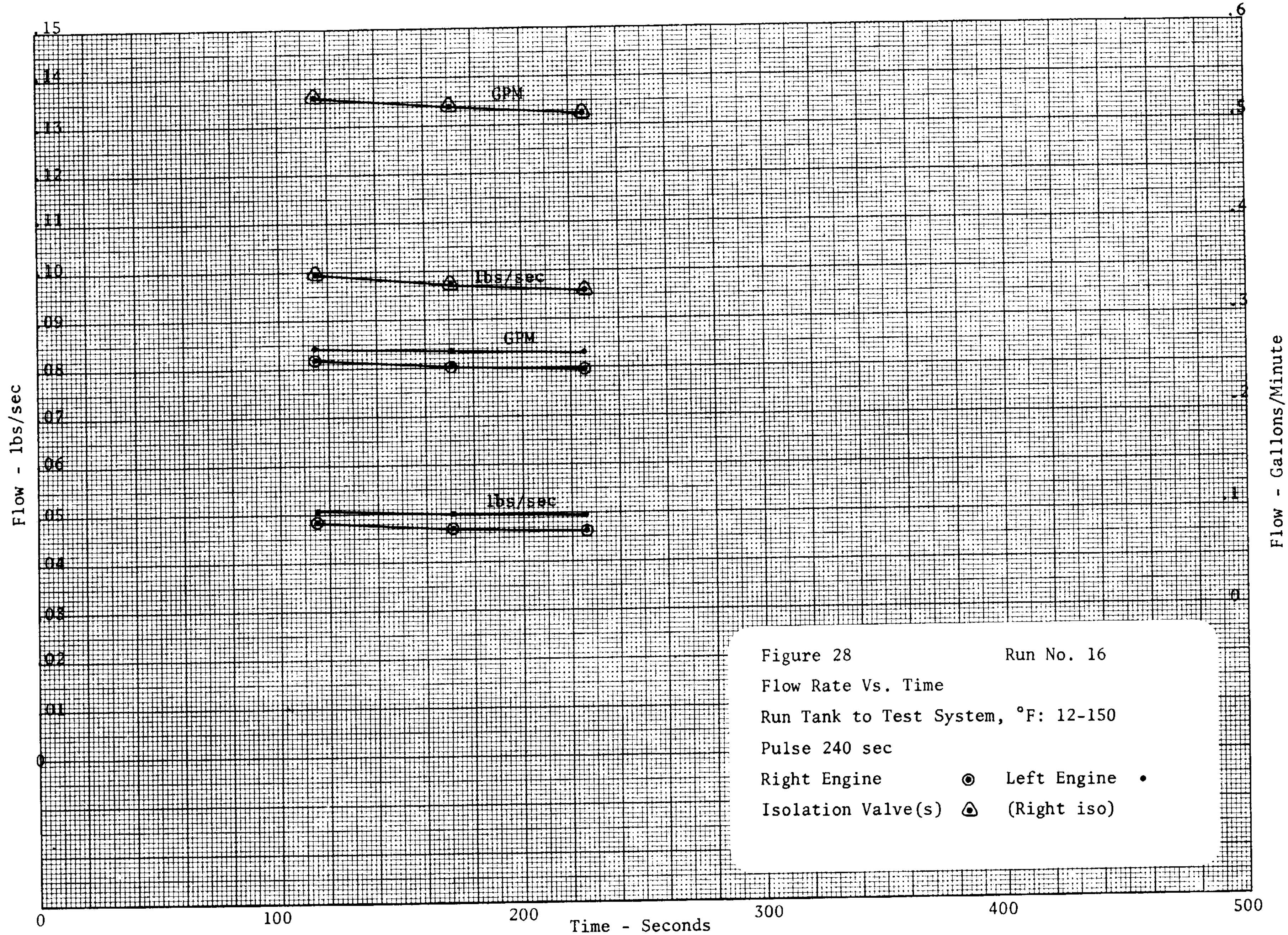


Figure 28 Run No. 16

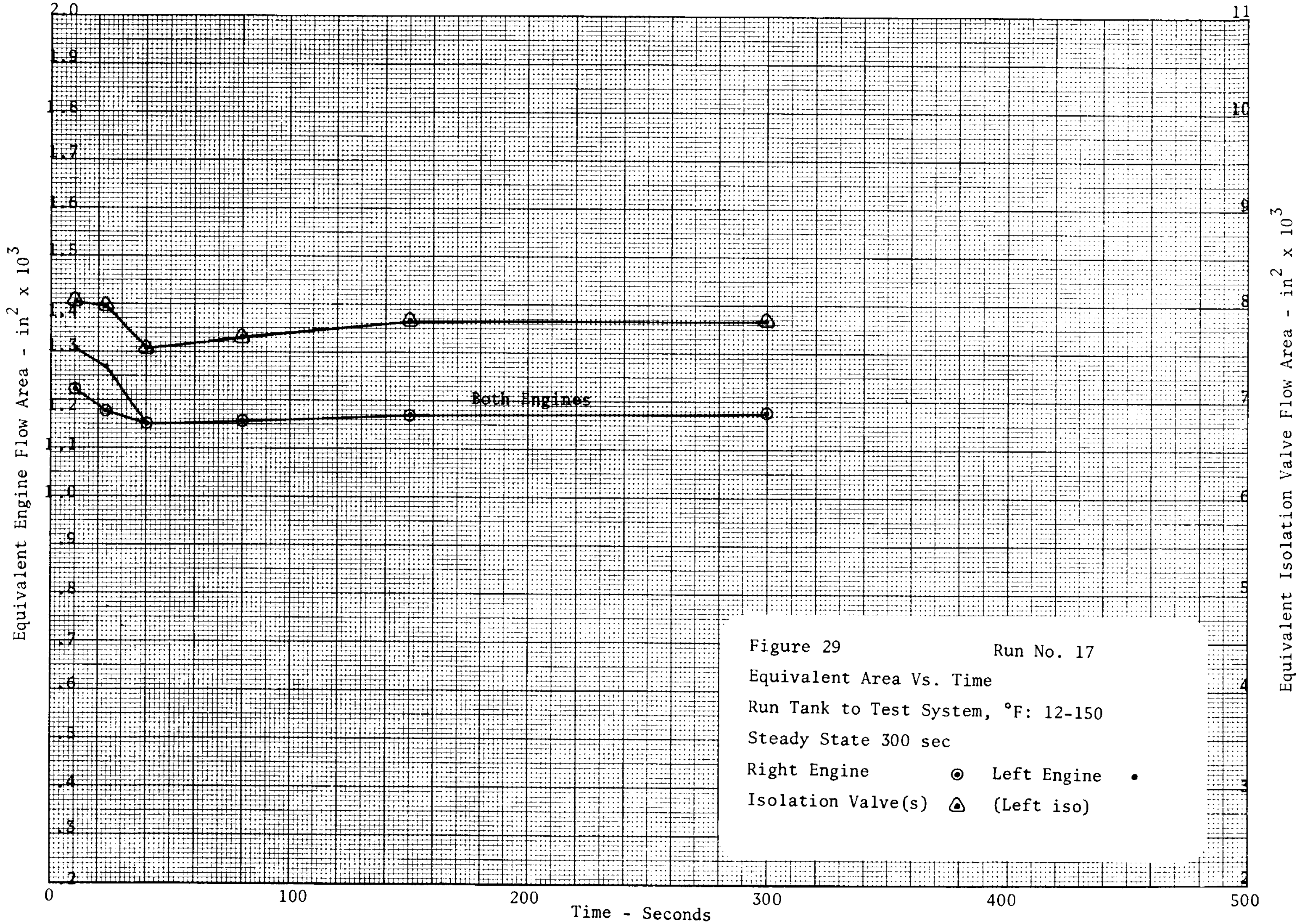
Flow Rate Vs. Time

Run Tank to Test System, °F: 12-150

Pulse 240 sec

Right Engine ◉ Left Engine •

Isolation Valve(s) ◬ (Right iso)


Equivalent Engine Flow Area - in^2 x 10^3
Equivalent Isolation Valve Flow Area - in^2 x 10^3
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2
Both Engines
Figure 29
Run No. 17
Equivalent Area Vs. Time
Run Tank to Test System, °F: 12-150
Steady State 300 sec
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)

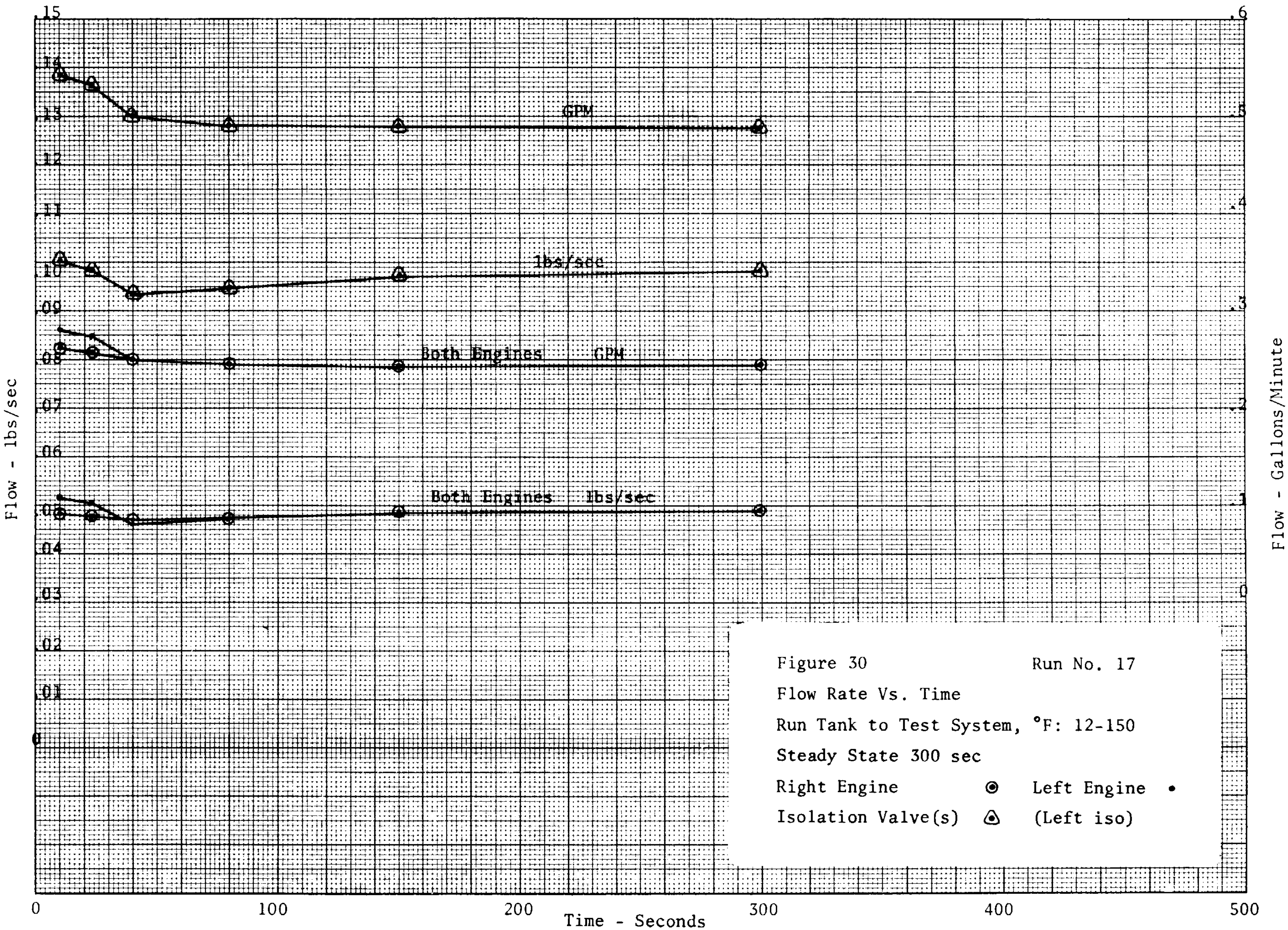


Figure 30 Run No. 17

Flow Rate Vs. Time

Run Tank to Test System, °F: 12-150

Steady State 300 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Left iso)

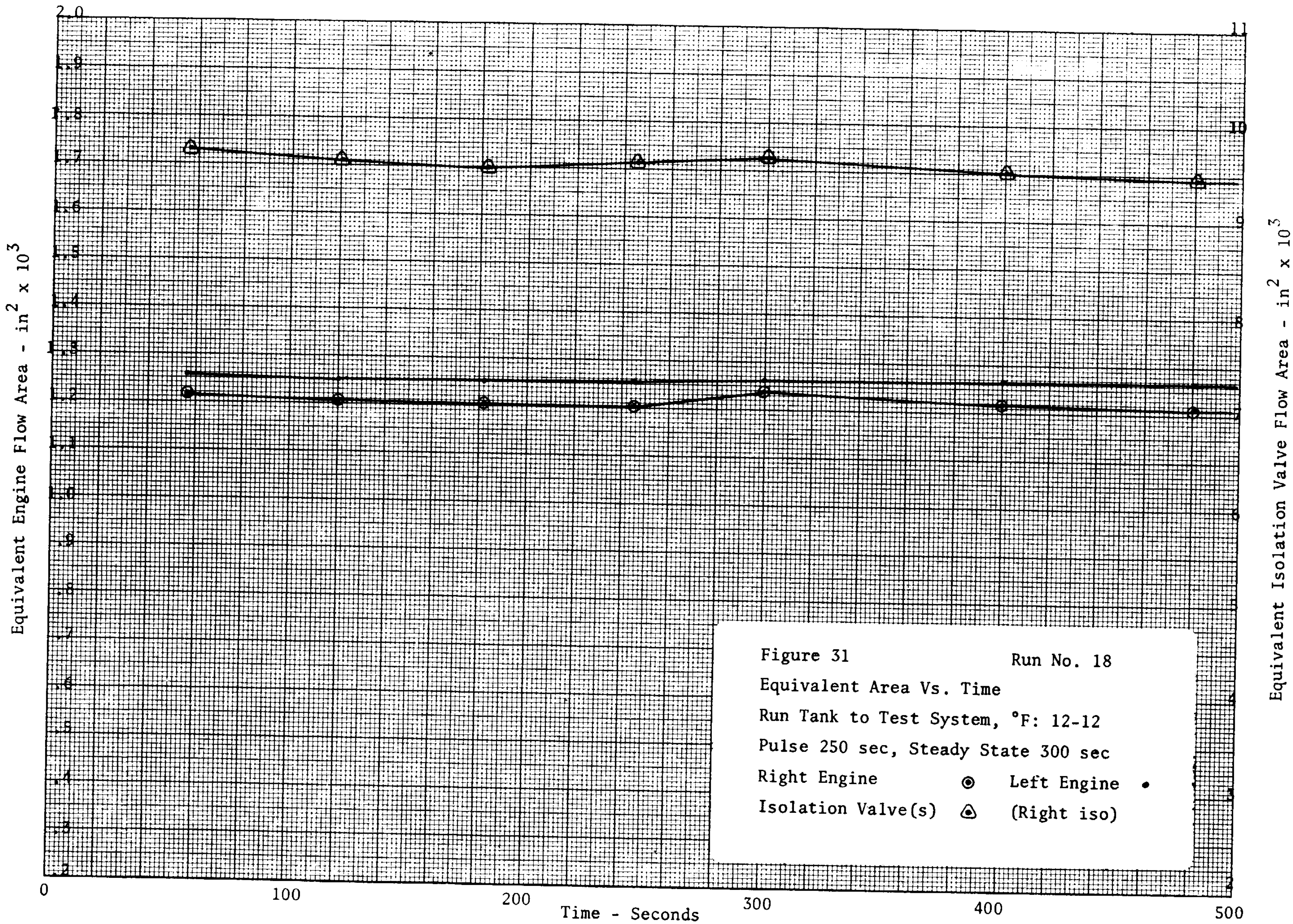


Figure 31 Run No. 18

Equivalent Area Vs. Time

Run Tank to Test System, °F: 12-12

Pulse 250 sec, Steady State 300 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Right iso)

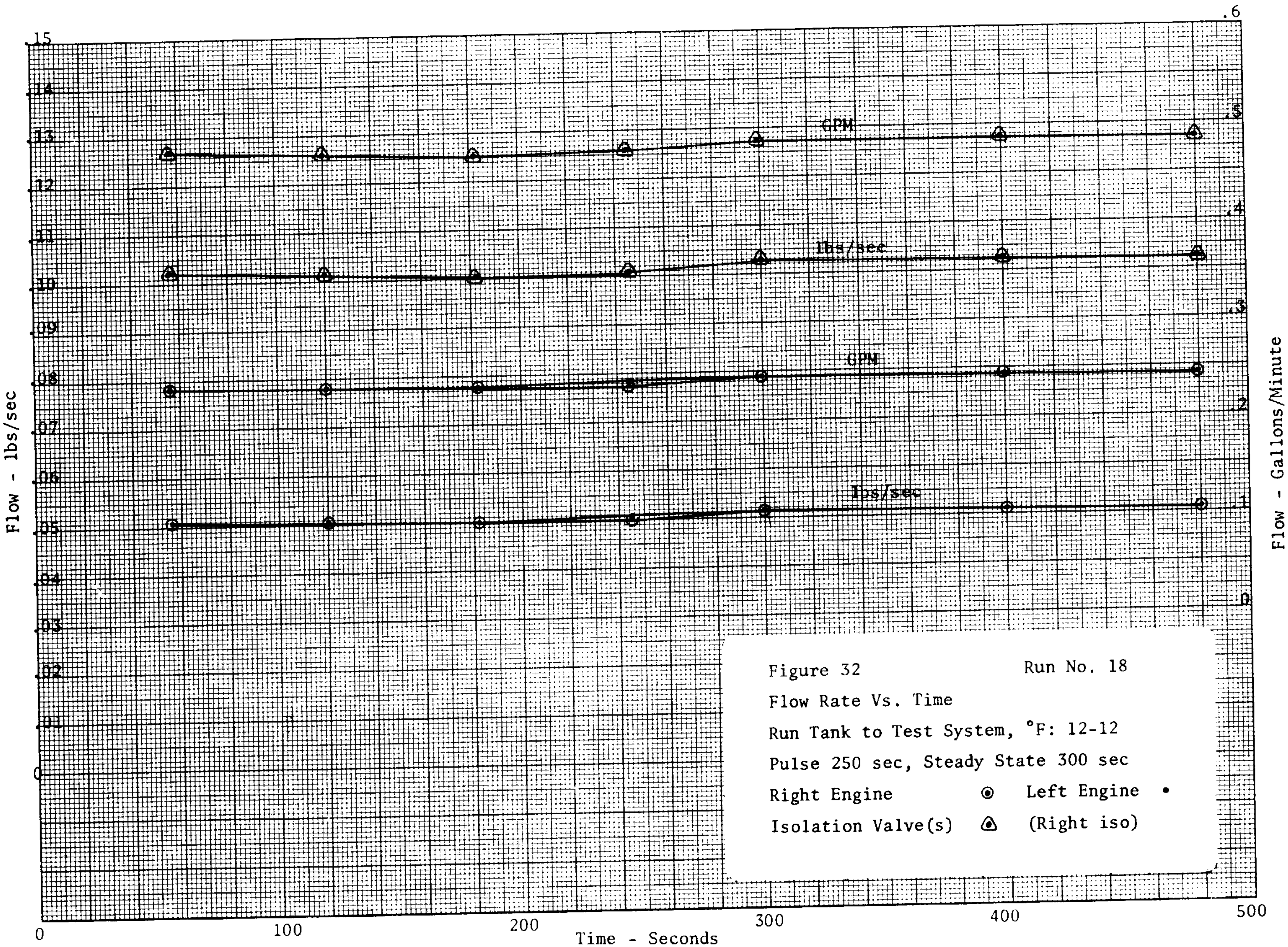


Figure 32 Run No. 18

Flow Rate Vs. Time

Run Tank to Test System, °F: 12-12

Pulse 250 sec, Steady State 300 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Right iso)

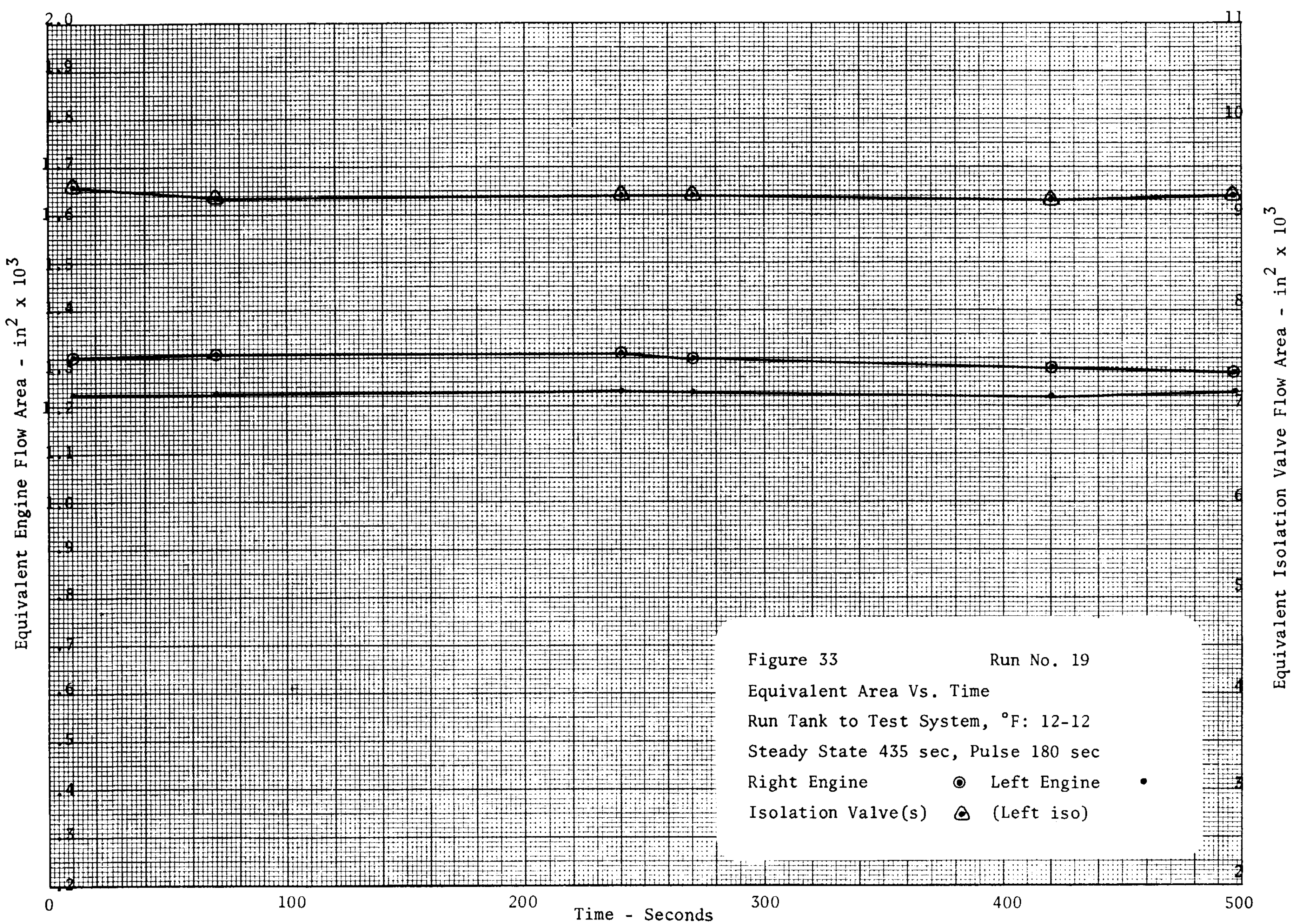


Figure 33 Run No. 19
Equivalent Area Vs. Time
Run Tank to Test System, °F: 12-12
Steady State 435 sec, Pulse 180 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) (Left iso)
Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2

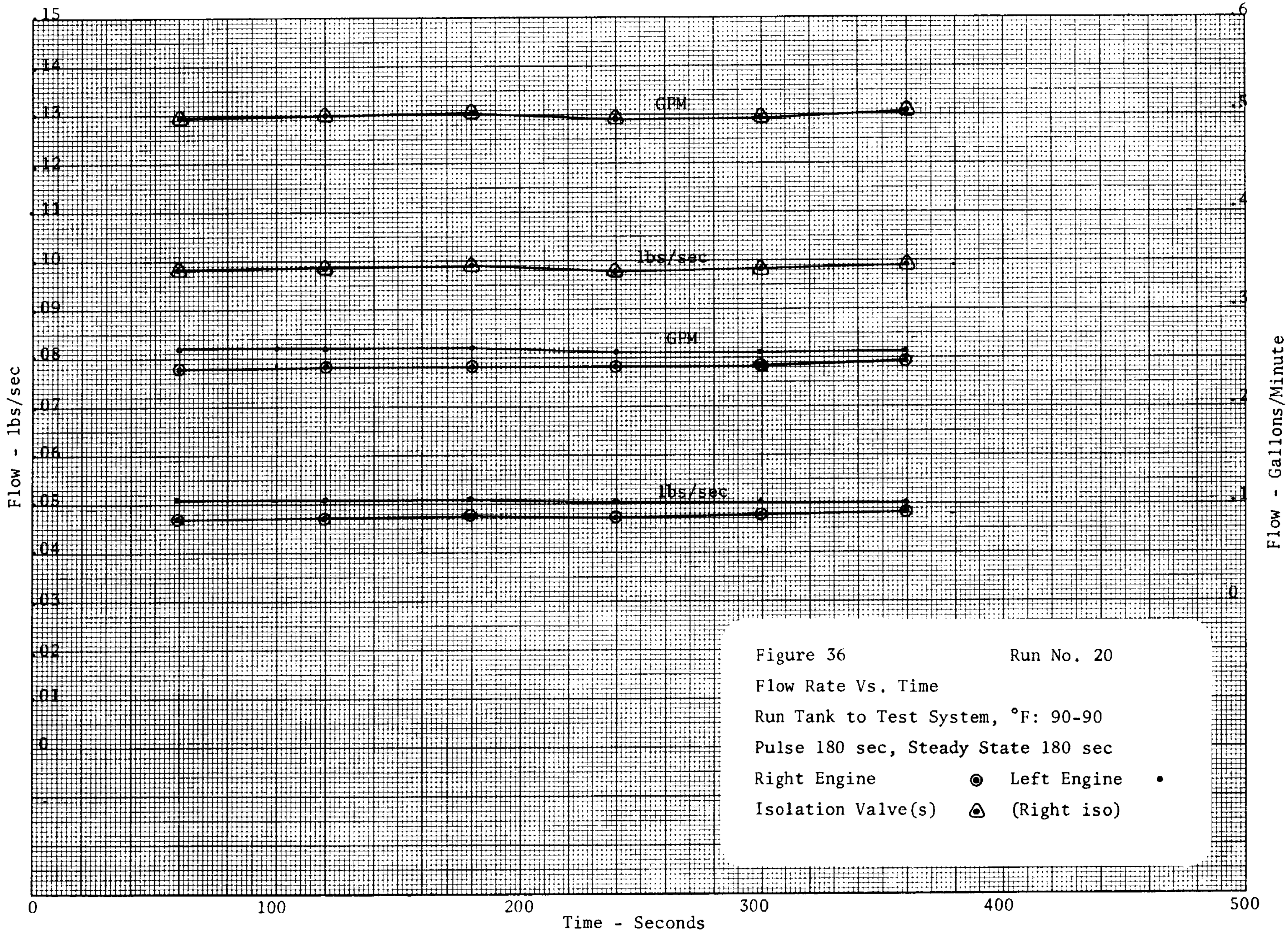


Figure 36 Run No. 20

Flow Rate Vs. Time

Run Tank to Test System, °F: 90-90

Pulse 180 sec, Steady State 180 sec

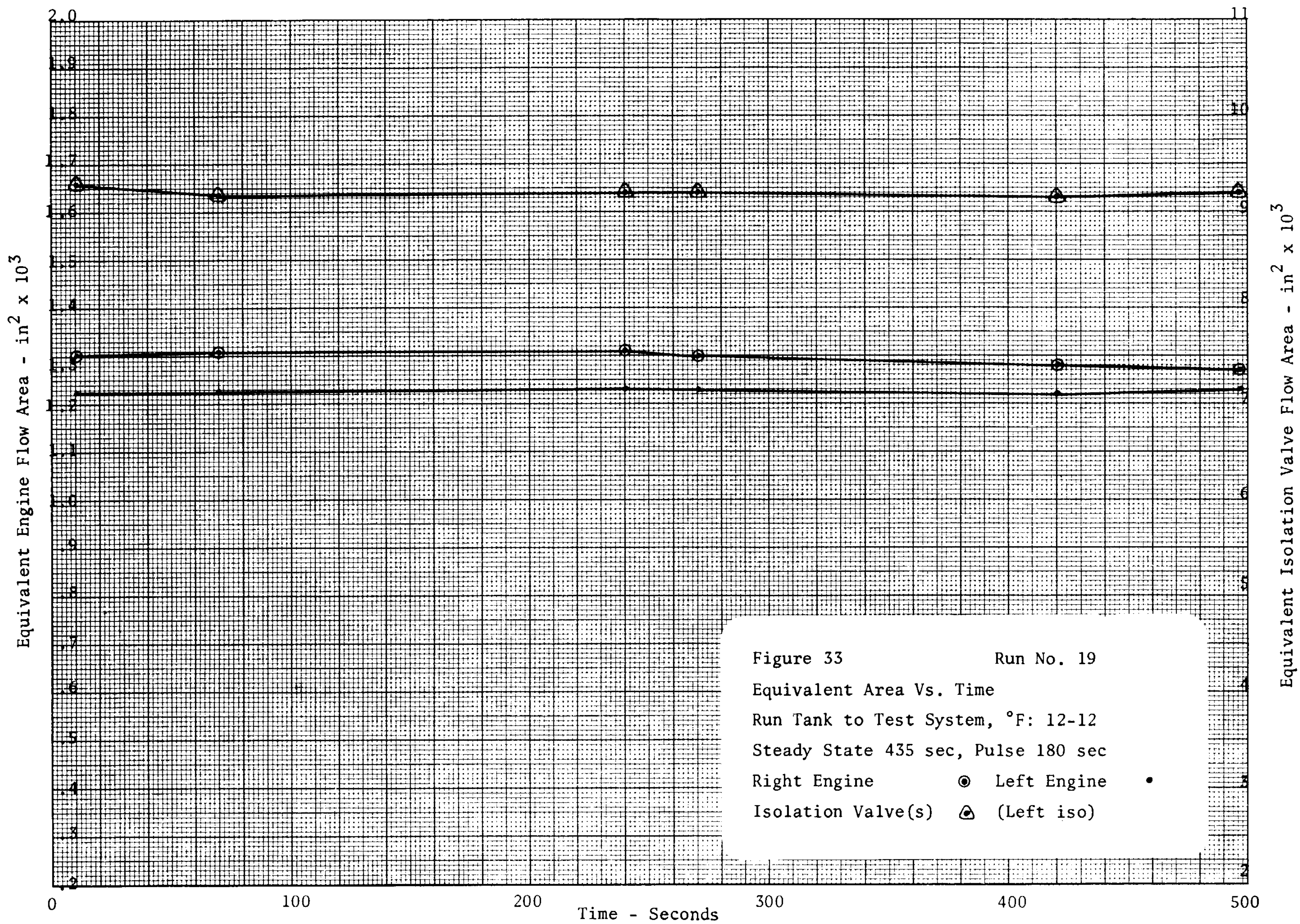


Figure 33 Run No. 19

Equivalent Area Vs. Time

Run Tank to Test System, °F: 12-12

Steady State 435 sec, Pulse 180 sec

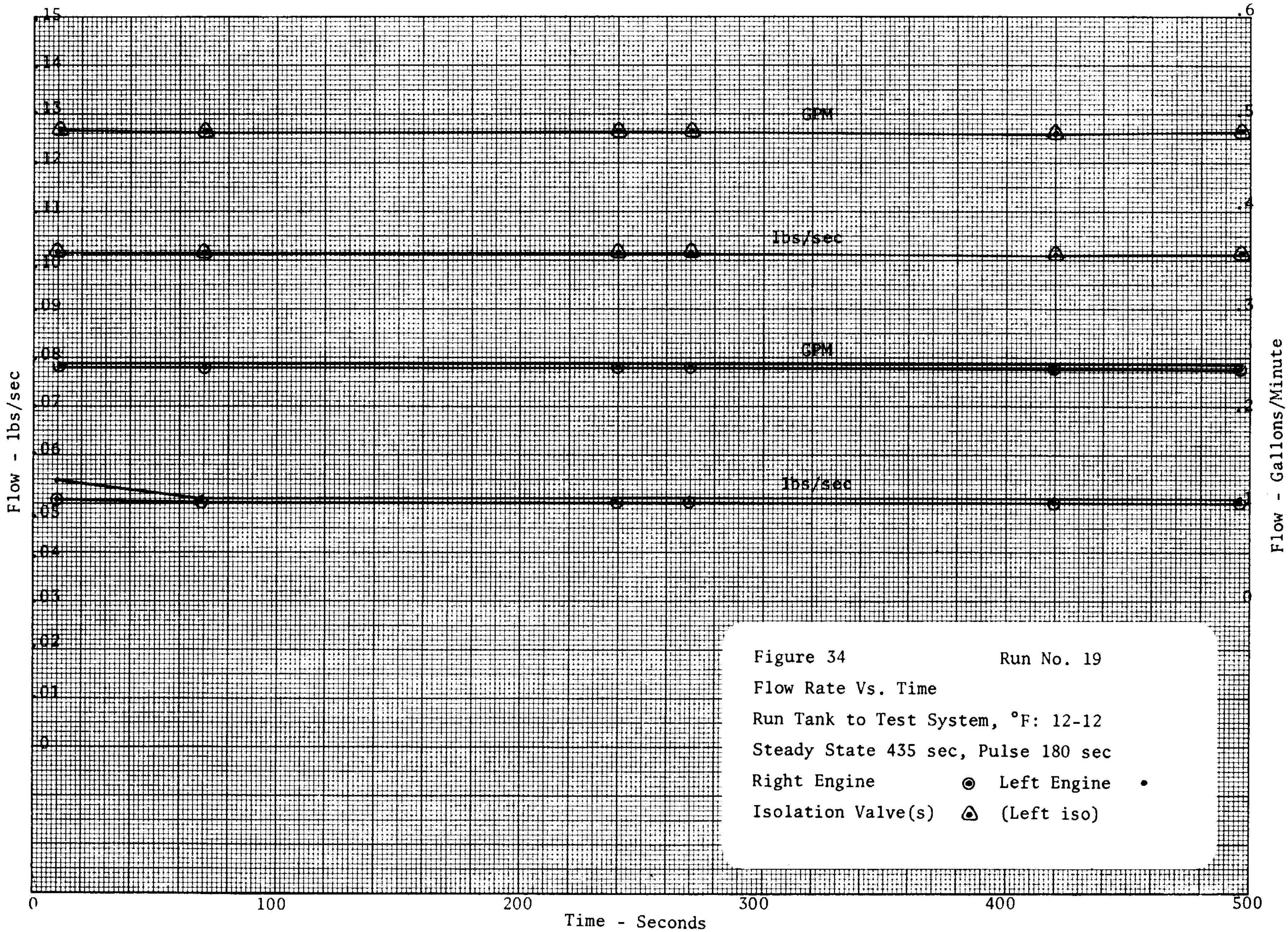
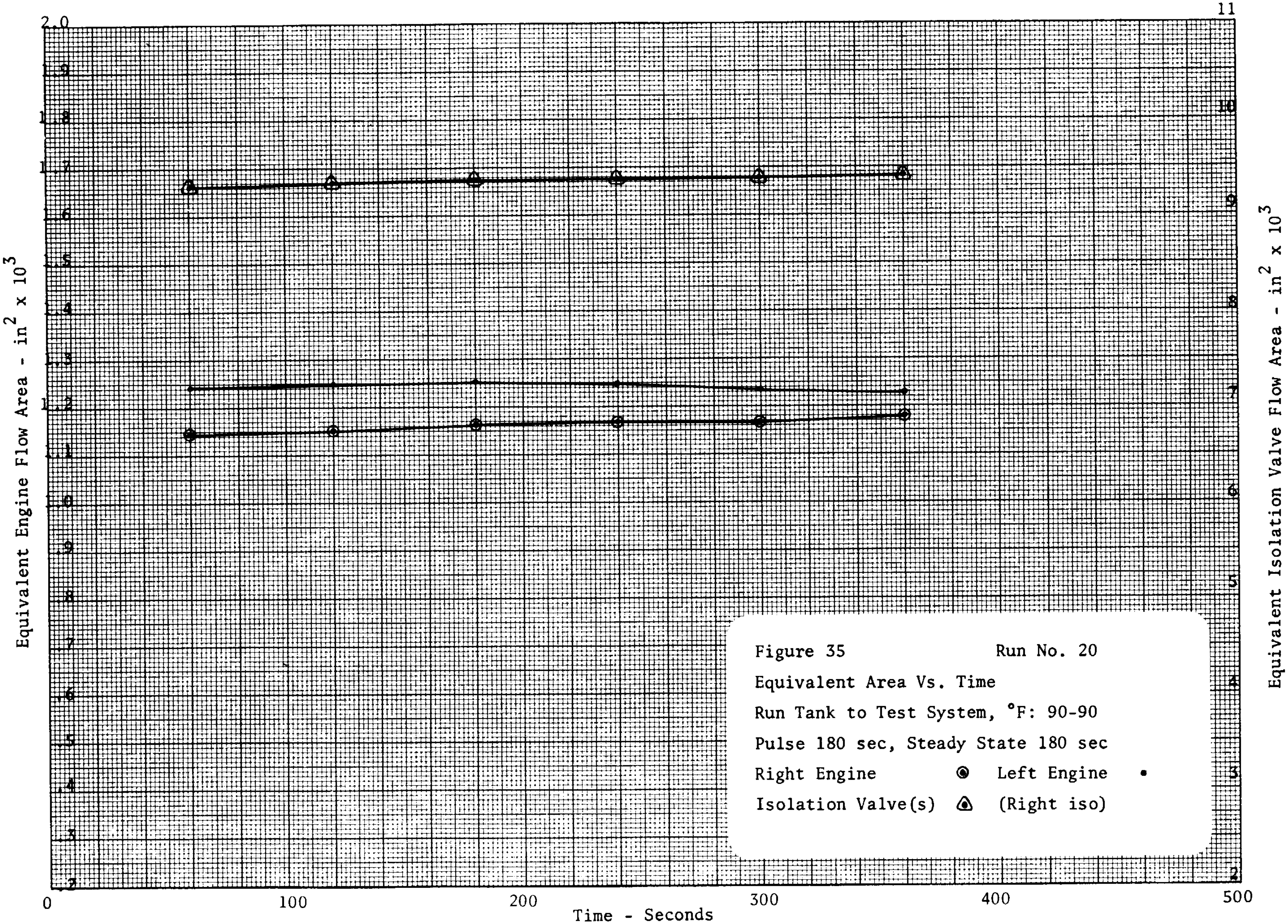
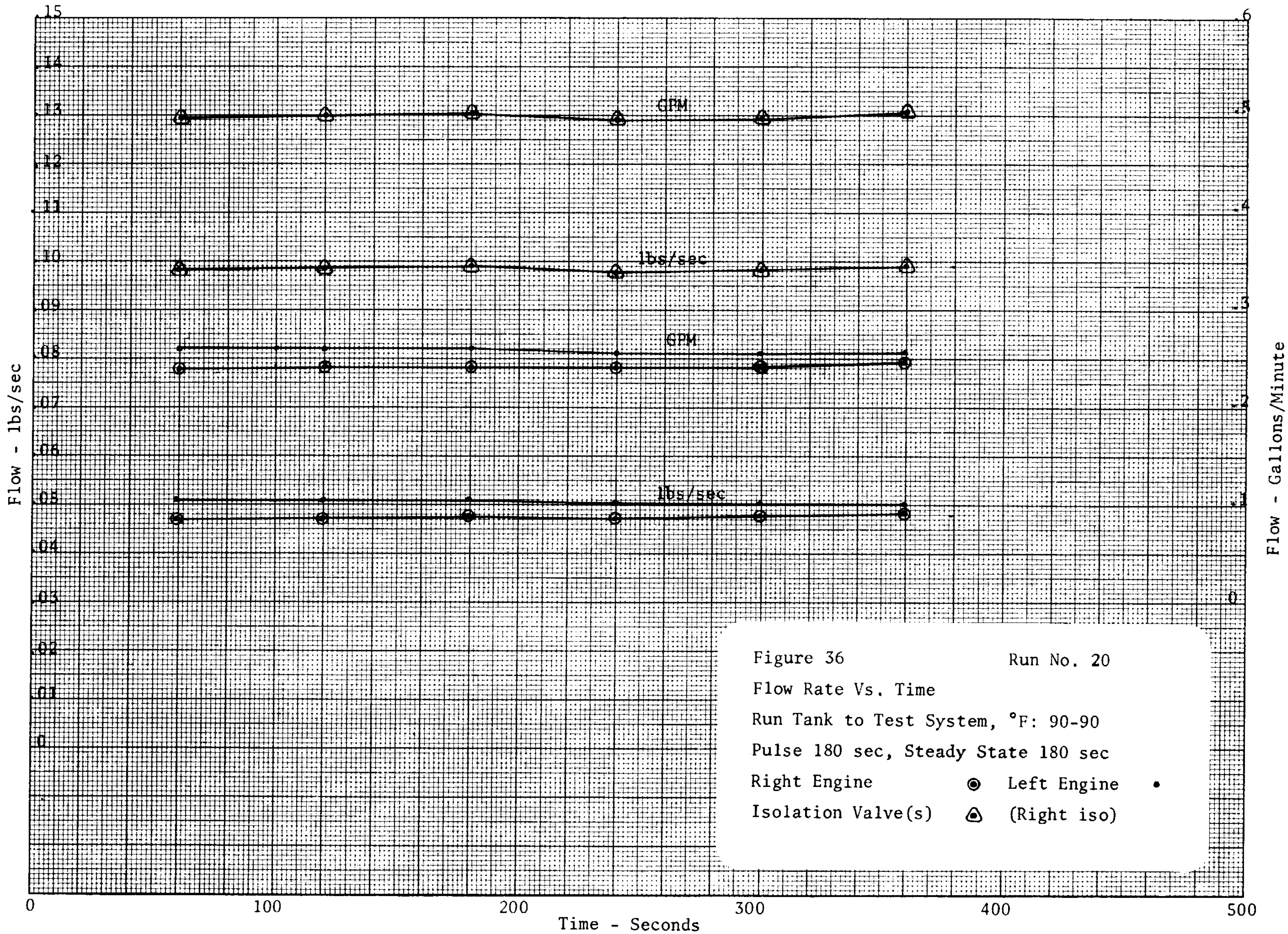


Figure 34 Run No. 19
Flow Rate Vs. Time
Run Tank to Test System, °F: 12-12
Steady State 435 sec, Pulse 180 sec
Right Engine ◉ Left Engine •
Isolation Valve(s) (Left iso)
GPM
lbs/sec
GPM
lbs/sec
Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
.6
.5
.4
.3
.2
.1
0
0
100
200
300
400
500



Equivalent Engine Flow Area - $in^2 \times 10^3$
Equivalent Isolation Valve Flow Area - $in^2 \times 10^3$
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2
Figure 35
Run No. 20
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-90
Pulse 180 sec, Steady State 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)


.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
Flow - lbs/sec
.6
.5
.4
.3
.2
.1
0
Flow - Gallons/Minute
GPM
lbs/sec
GPM
lbs/sec
0
100
200
300
400
500
Time - Seconds
Figure 36
Run No. 20
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-90
Pulse 180 sec, Steady State 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)

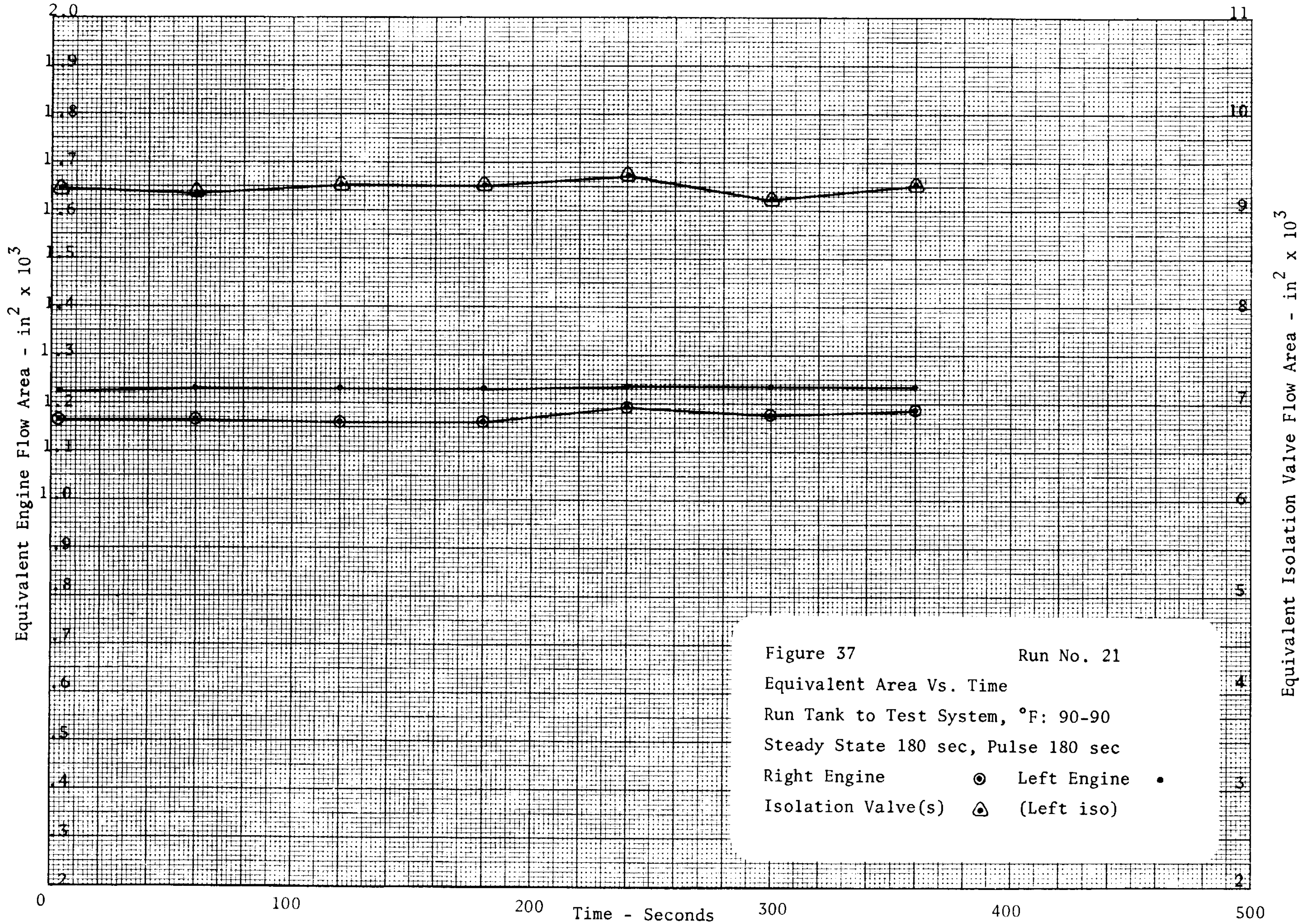


Figure 37 Run No. 21

Equivalent Area Vs. Time

Run Tank to Test System, °F: 90-90

Steady State 180 sec, Pulse 180 sec

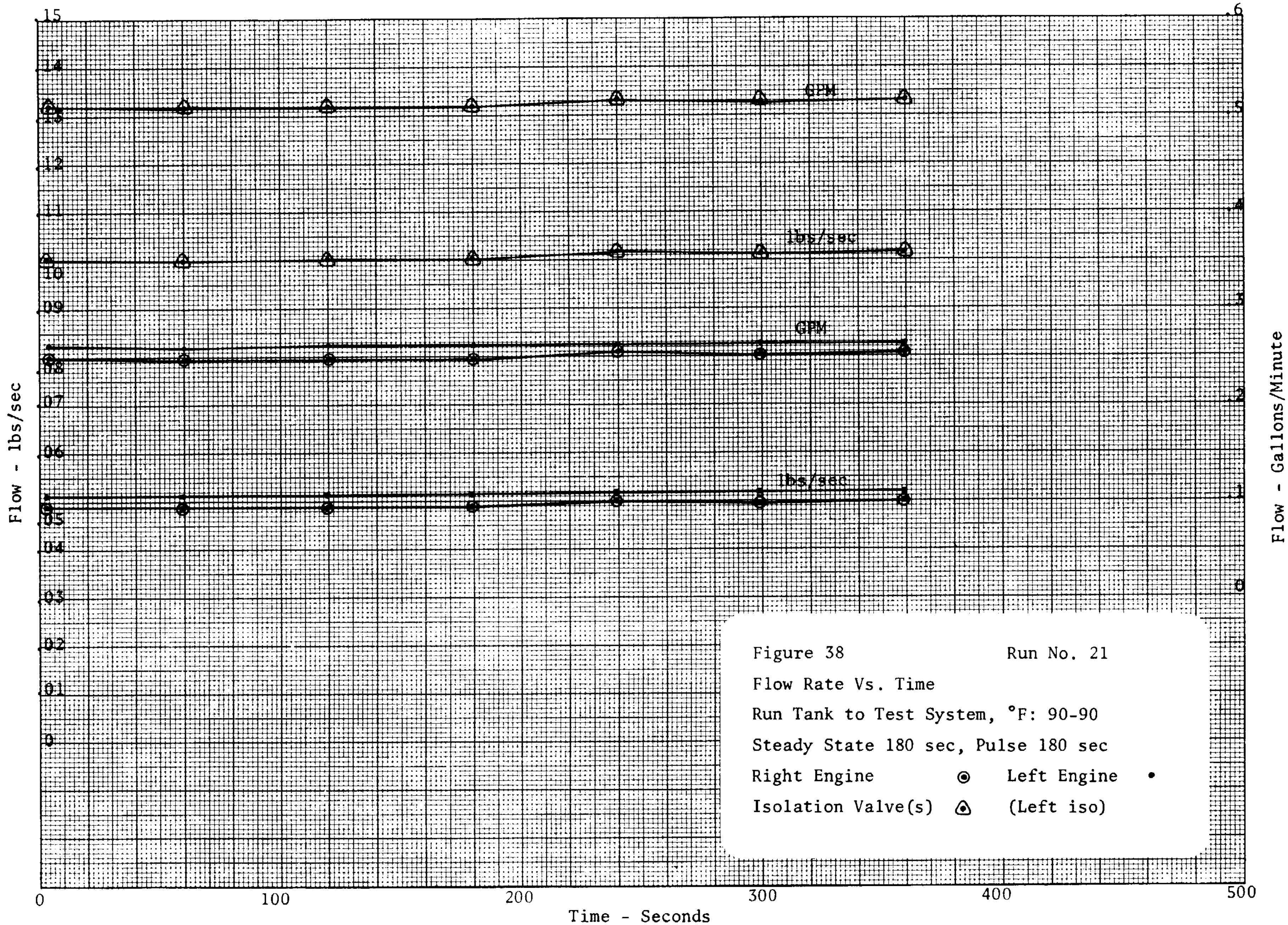
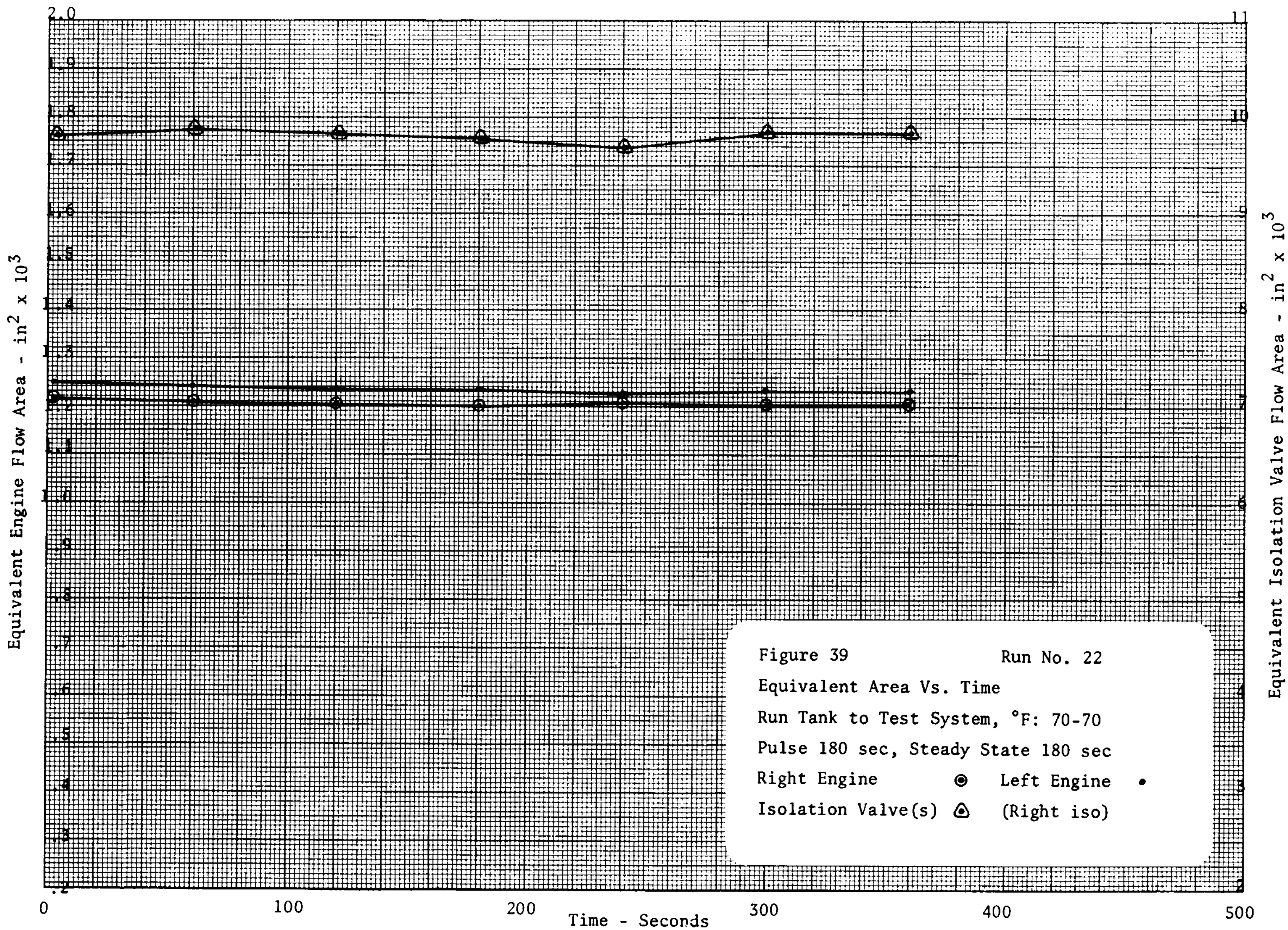


Figure 38 Run No. 21
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-90
Steady State 180 sec, Pulse 180 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Left iso)



Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2
Figure 39
Run No. 22
Equivalent Area Vs. Time
Run Tank to Test System, °F: 70-70
Pulse 180 sec, Steady State 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)

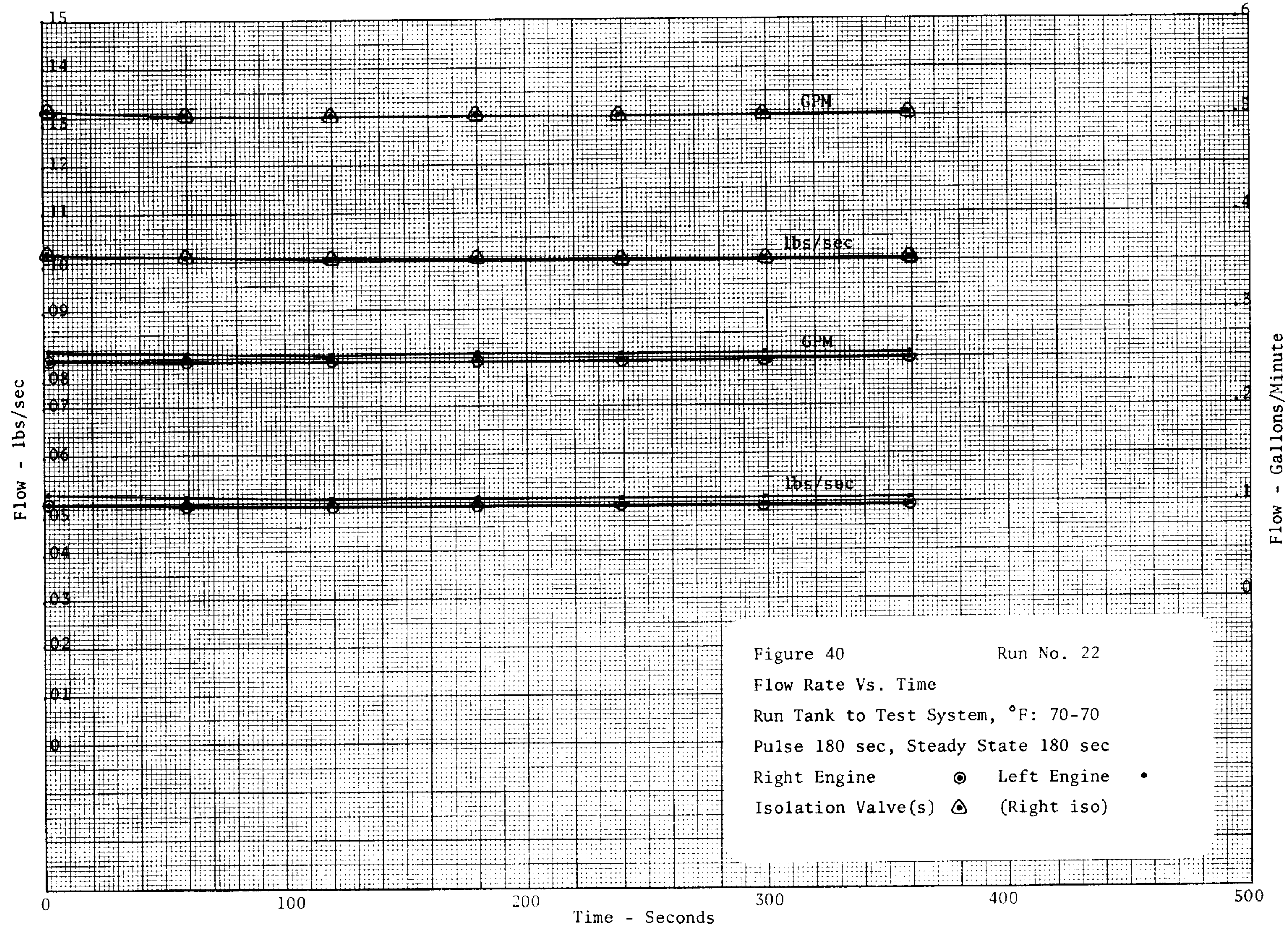


Figure 40 Run No. 22

Flow Rate Vs. Time

Run Tank to Test System, °F: 70-70

Pulse 180 sec, Steady State 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) ⊙ (Right iso)

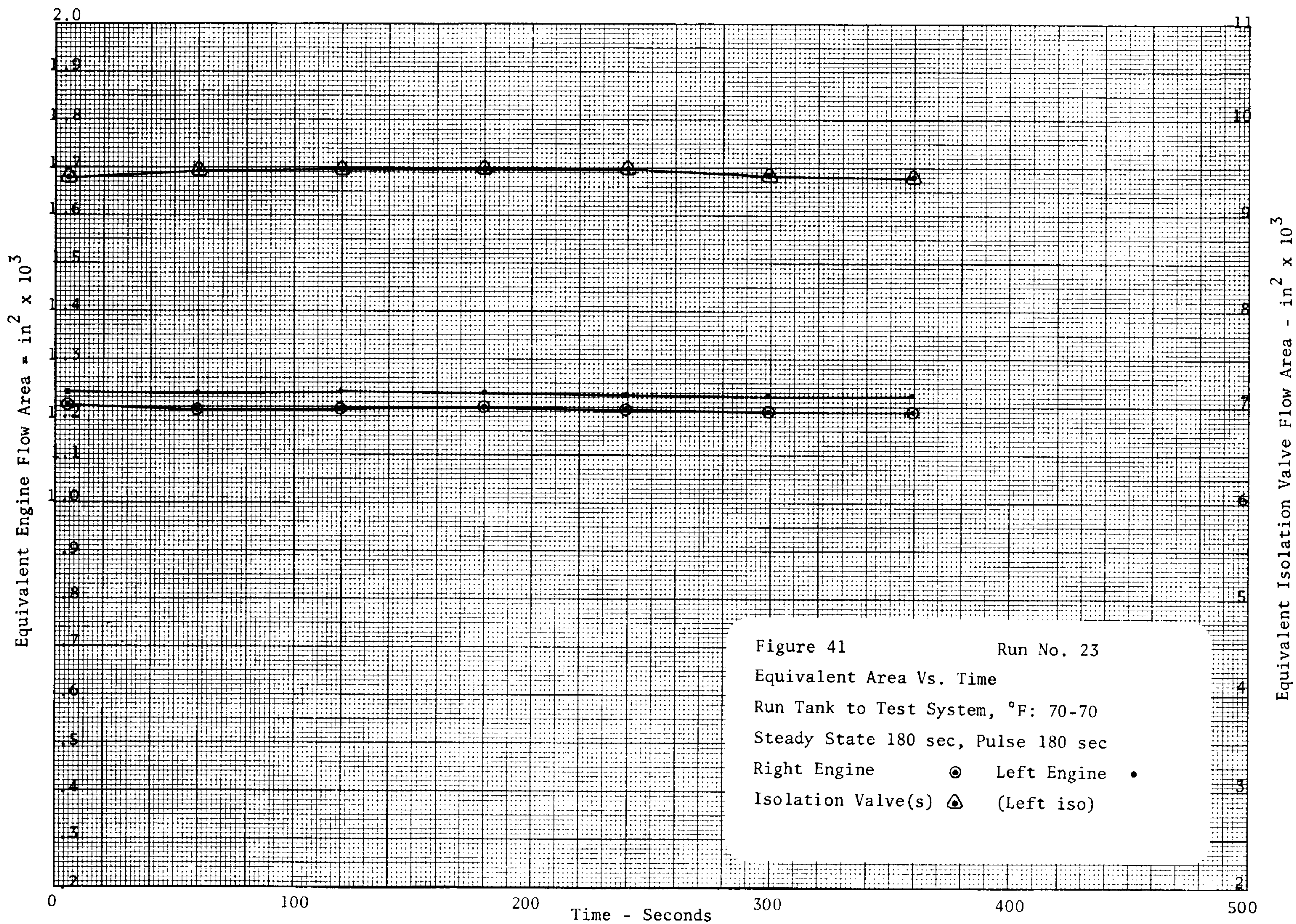
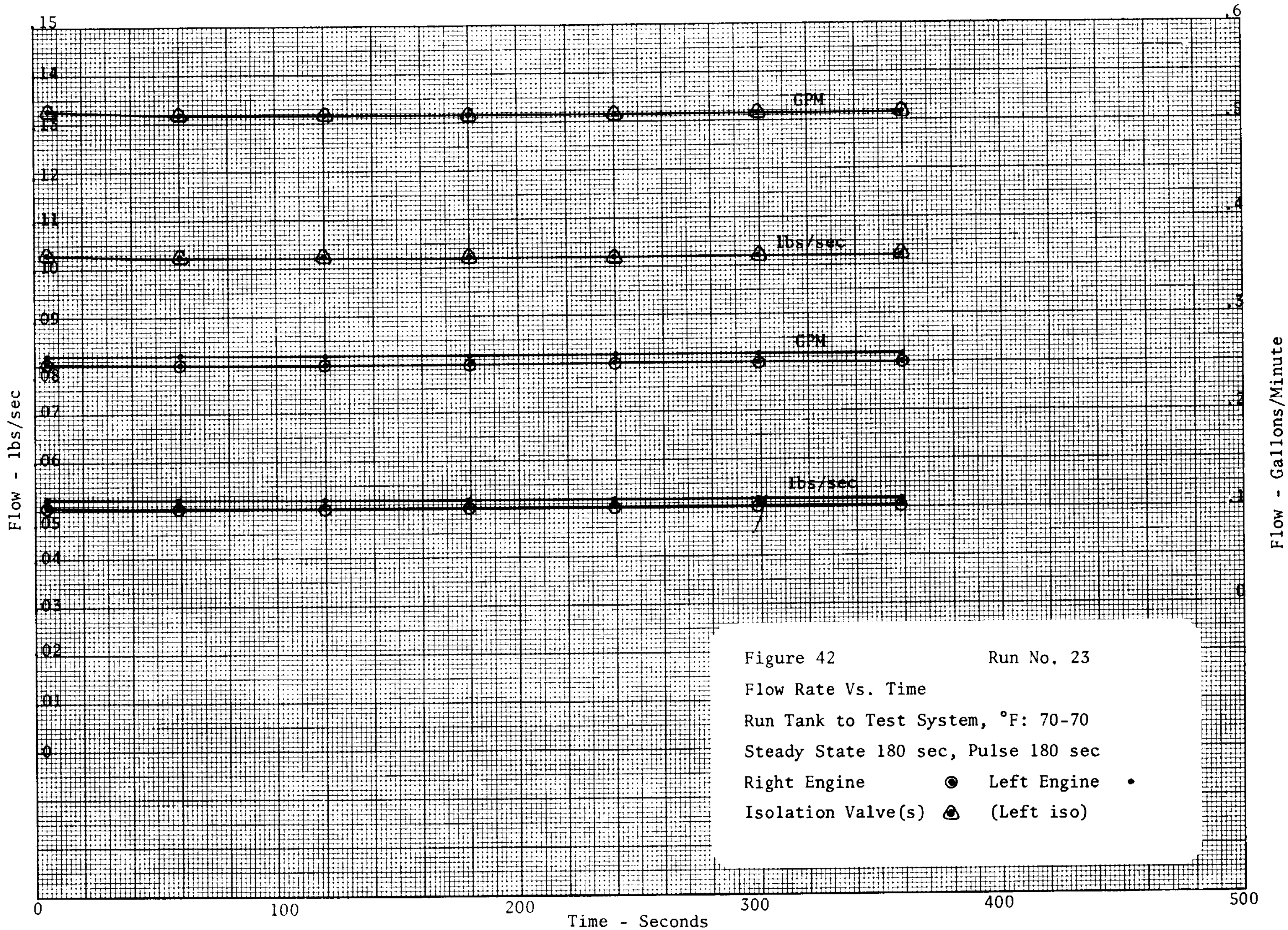
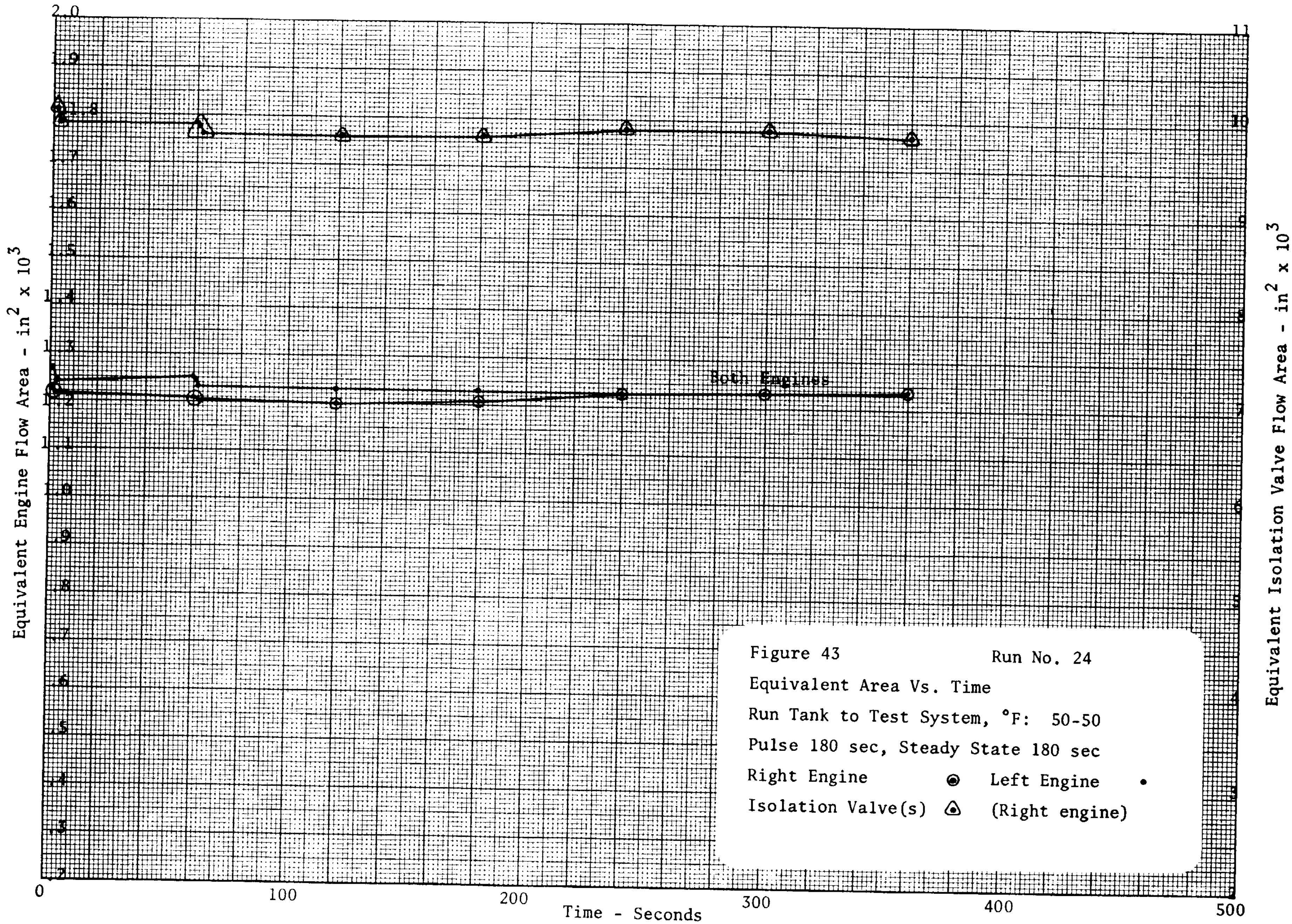


Figure 41
Run No. 23
Equivalent Area Vs. Time
Run Tank to Test System, °F: 70-70
Steady State 180 sec, Pulse 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)
Equivalent Engine Flow Area = in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2



GPM
lbs/sec
GPM
lbs/sec
Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
.6
.5
.4
.3
.2
.1
0
0
100
200
300
400
500
Figure 42
Run No. 23
Flow Rate Vs. Time
Run Tank to Test System, °F: 70-70
Steady State 180 sec, Pulse 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)



Equivalent Engine Flow Area - in^2 x 10^3
Equivalent Isolation Valve Flow Area - in^2 x 10^3
Time - Seconds
0
100
200
300
400
500
Both Engines
Figure 43
Run No. 24
Equivalent Area Vs. Time
Run Tank to Test System, °F: 50-50
Pulse 180 sec, Steady State 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Right engine)

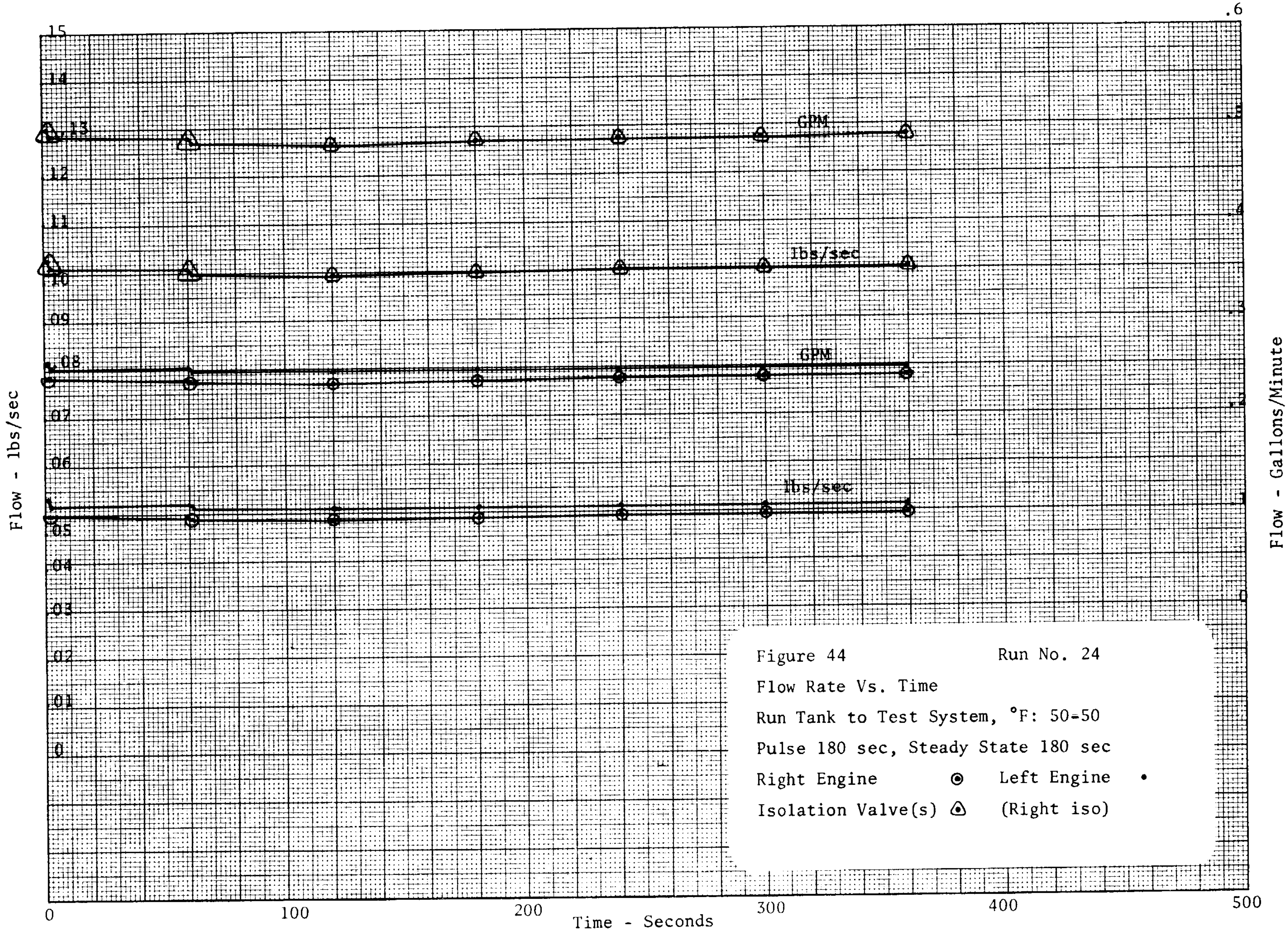


Figure 44 Run No. 24

Flow Rate Vs. Time

Run Tank to Test System, °F: 50-50

Pulse 180 sec, Steady State 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Right iso)

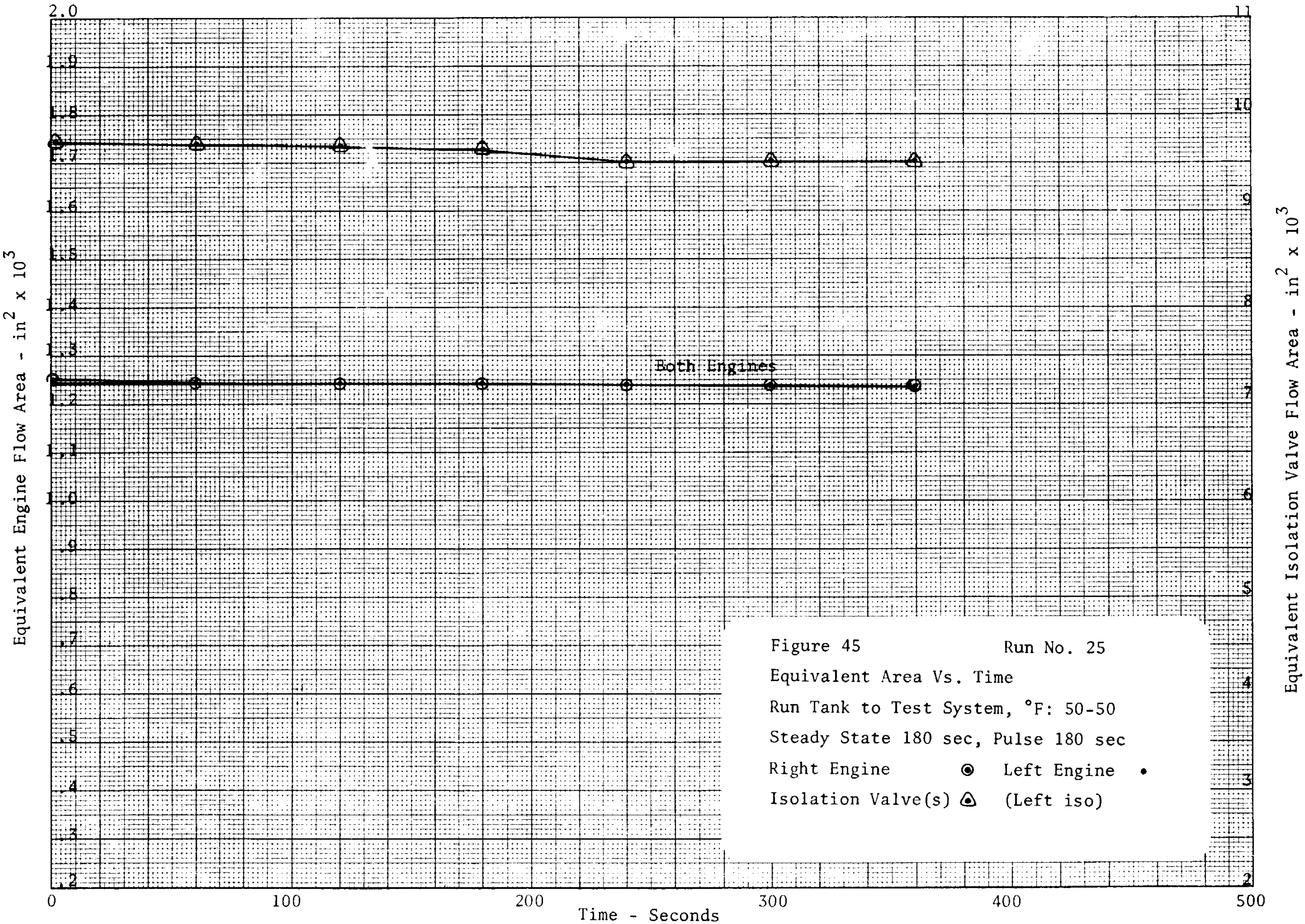


Figure 45 Run No. 25

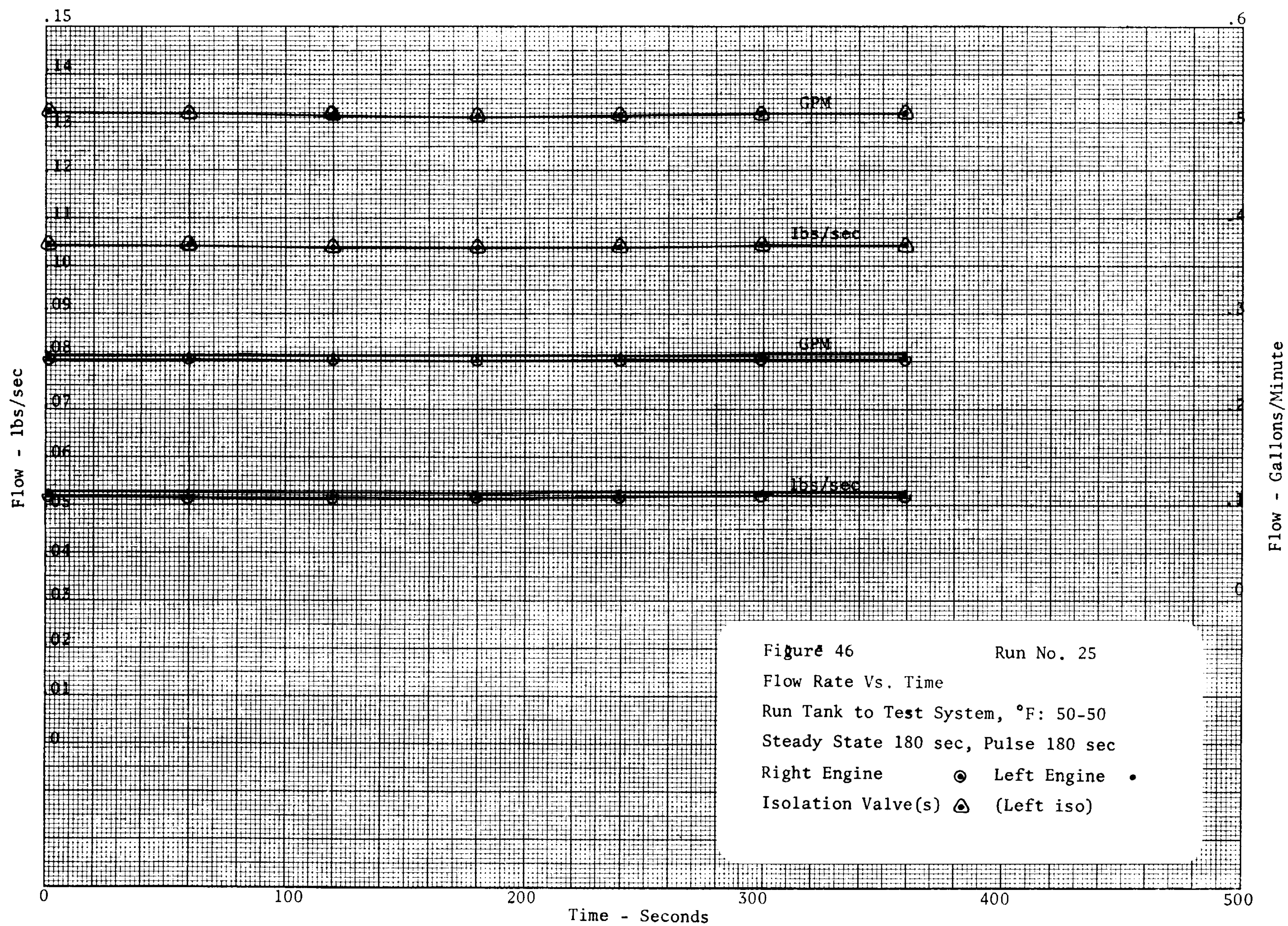
Equivalent Area Vs. Time

Run Tank to Test System, °F: 50-50

Steady State 180 sec, Pulse 180 sec

Right Engine ◉ Left Engine •

Isolation Valve(s) ◬ (Left iso)



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.5
.4
.3
.2
.1
0
GPM
lbs/sec
GPM
lbs/sec
Flow - lbs/sec
Flow - Gallons/Minute
0
100
200
300
400
500
Time - Seconds
Figure 46
Run No. 25
Flow Rate Vs. Time
Run Tank to Test System, °F: 50-50
Steady State 180 sec, Pulse 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)

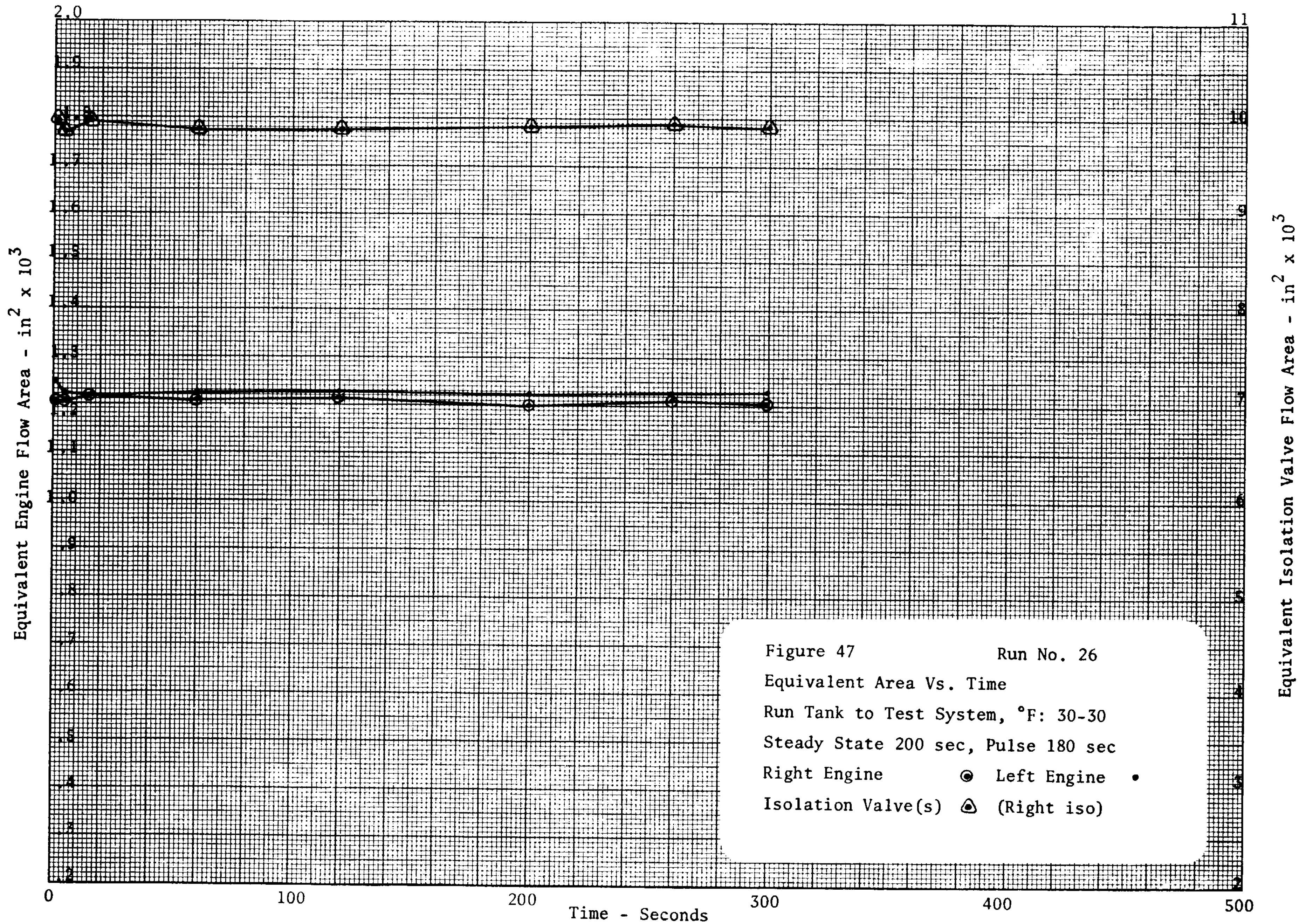
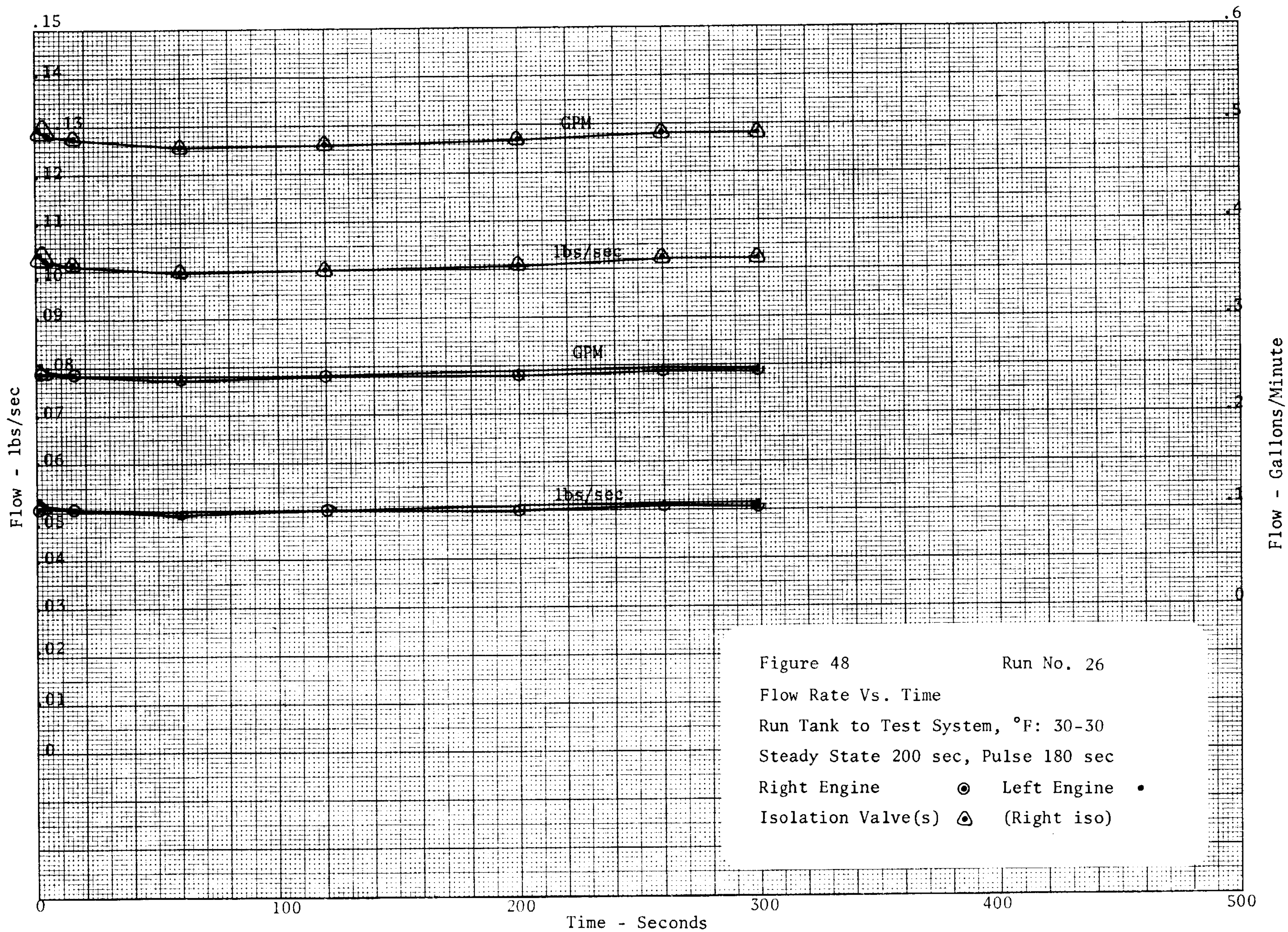


Figure 47
Run No. 26
Equivalent Area Vs. Time
Run Tank to Test System, °F: 30-30
Steady State 200 sec, Pulse 180 sec
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)
Equivalent Engine Flow Area - in^2 x 10^3
Equivalent Isolation Valve Flow Area - in^2 x 10^3
Time - Seconds
0
100
200
300
400
500
2.0
11
10



.15
.14
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.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
Flow - lbs/sec
.6
.5
.4
.3
.2
.1
0
Flow - Gallons/Minute
0
100
200
300
400
500
Time - Seconds
GPM
lbs/sec
GPM
lbs/sec
Figure 48 Run No. 26
Flow Rate Vs. Time
Run Tank to Test System, °F: 30-30
Steady State 200 sec, Pulse 180 sec
Right Engine ◉ Left Engine •
Isolation Valve(s) (Right iso)

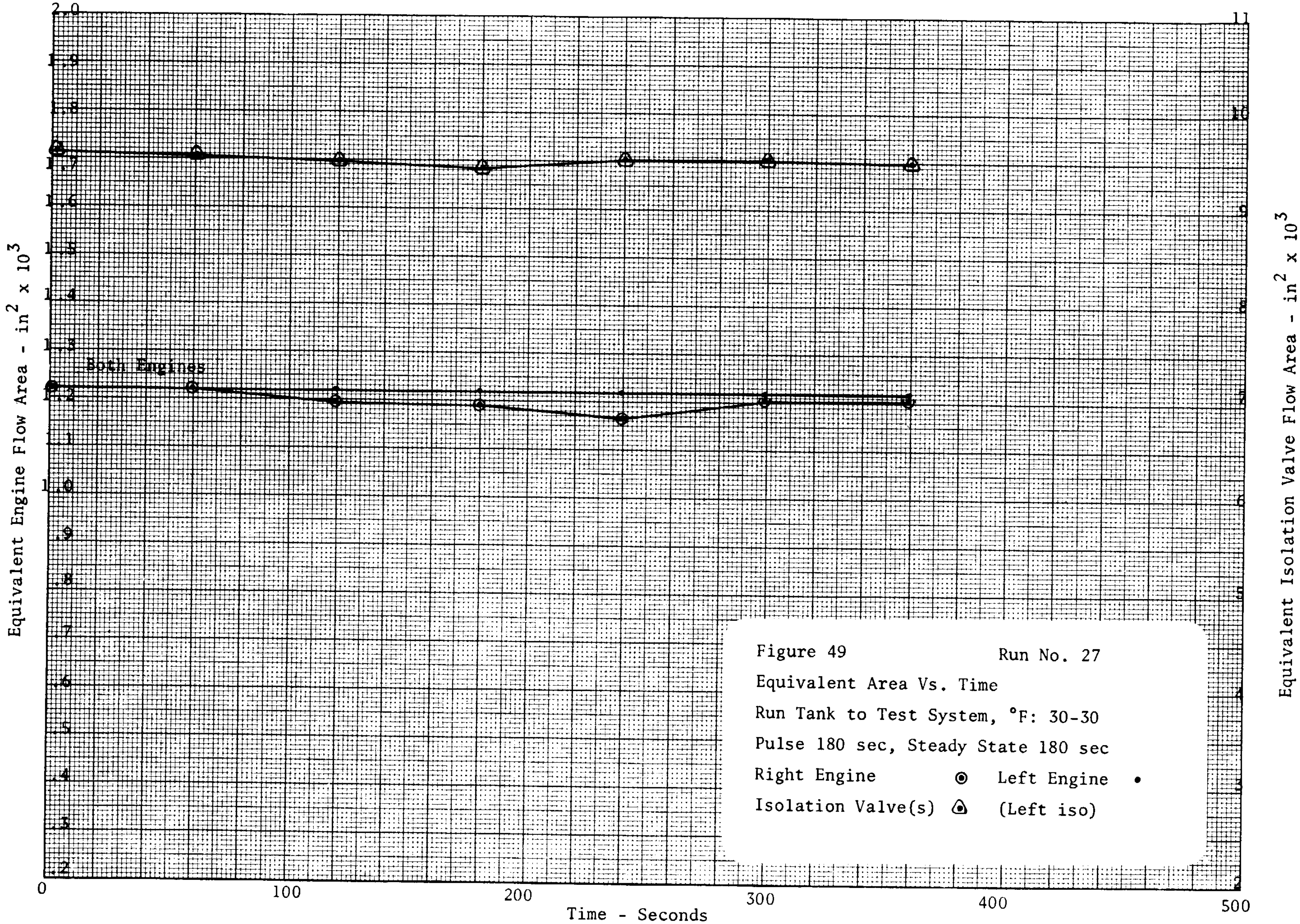

Figure 49 Run No. 27

Equivalent Area Vs. Time

Run Tank to Test System, °F: 30-30

Pulse 180 sec, Steady State 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Left iso)

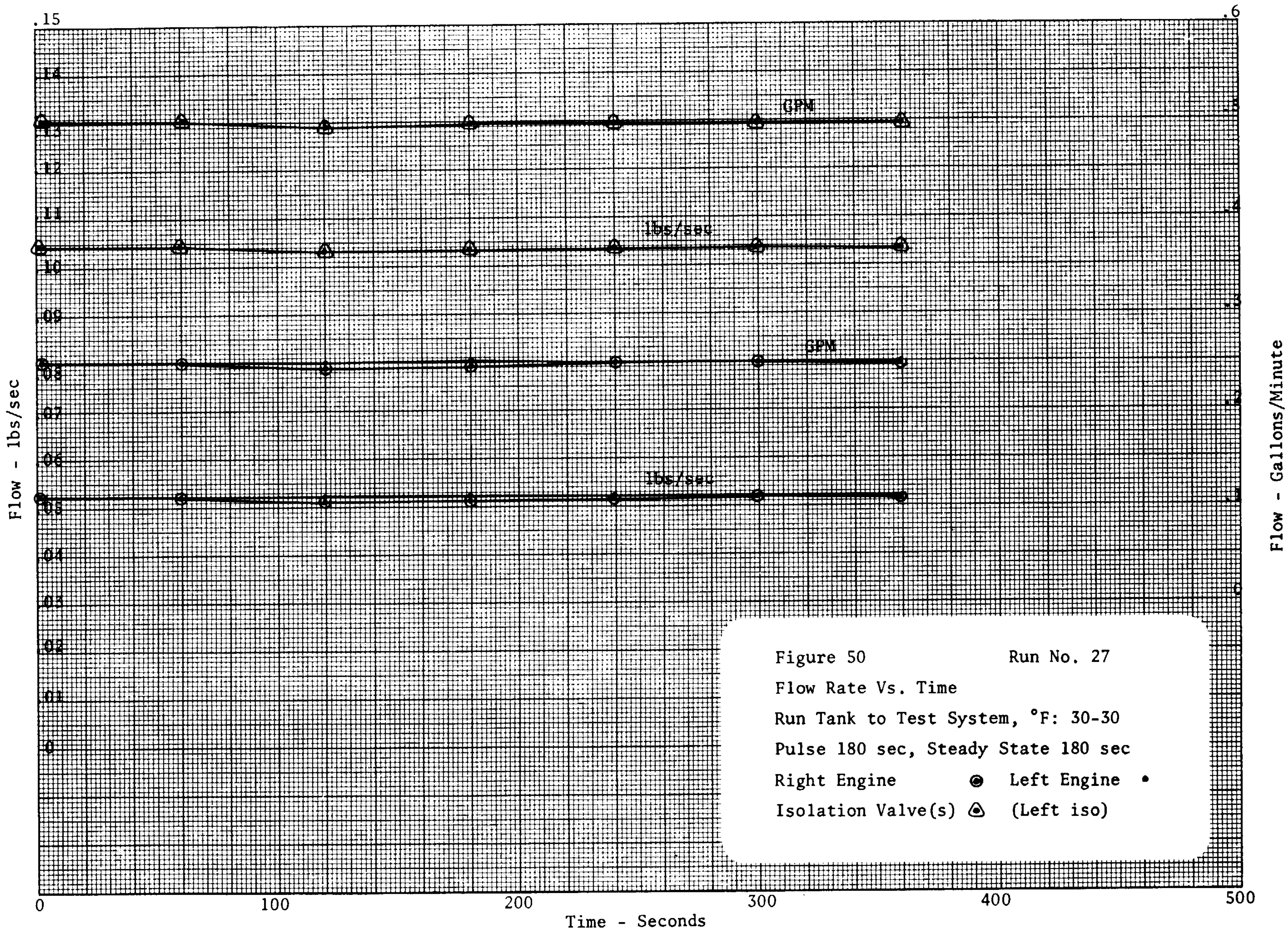

Figure 50 Run No. 27

Flow Rate Vs. Time

Run Tank to Test System, °F: 30-30

Pulse 180 sec, Steady State 180 sec

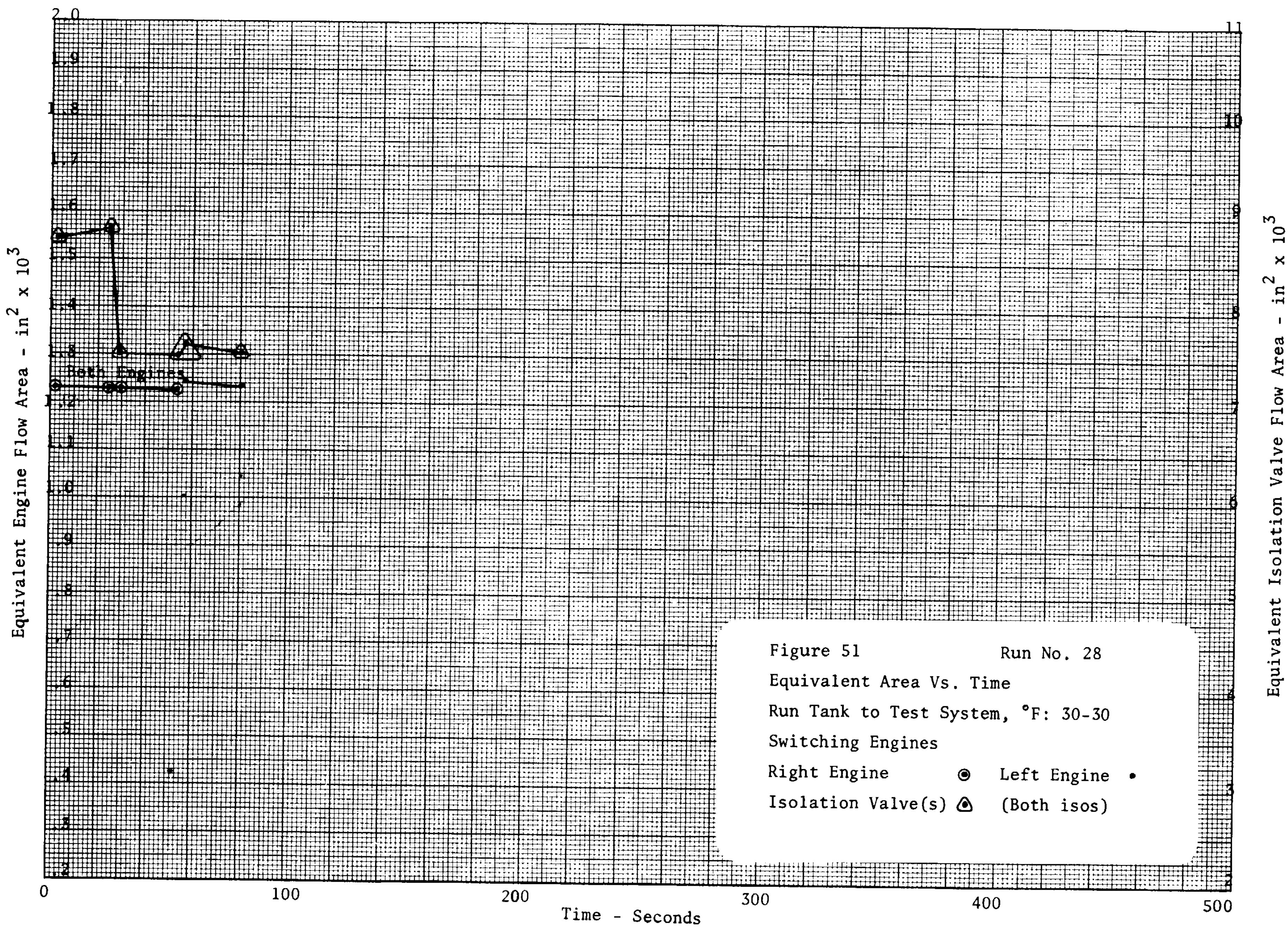
Figure 51
Run No. 28
Equivalent Area Vs. Time
Run Tank to Test System, °F: 30-30
Switching Engines
Right Engine
Left Engine
Isolation Valve(s)
(Both isos)
Both Engines
Equivalent Engine Flow Area - in^2 x 10^3
Equivalent Isolation Valve Flow Area - in^2 x 10^3
Time - Seconds
0
100
200
300
400
500

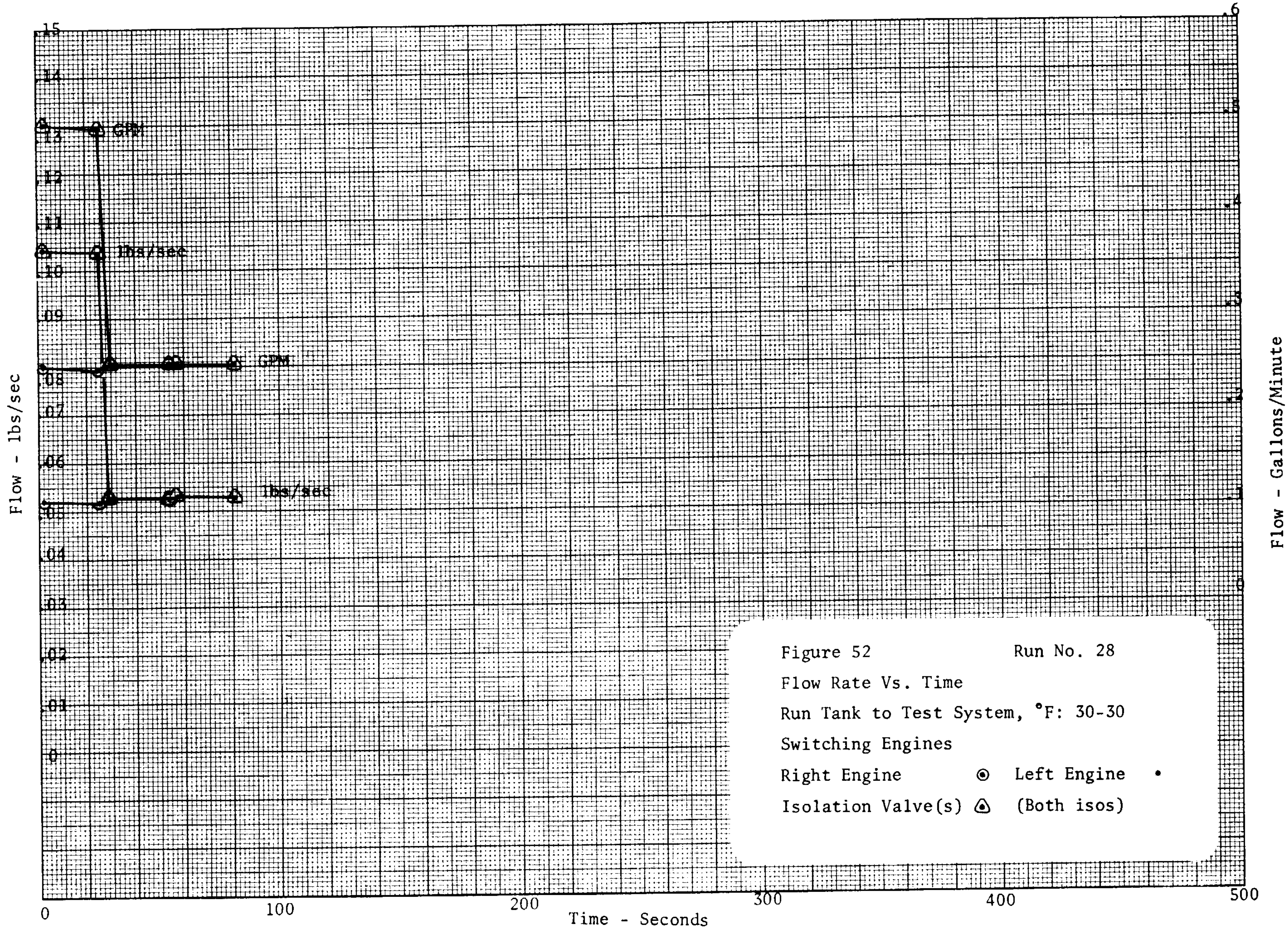

Figure 52 Run No. 28
Flow Rate Vs. Time
Run Tank to Test System, °F: 30-30
Switching Engines

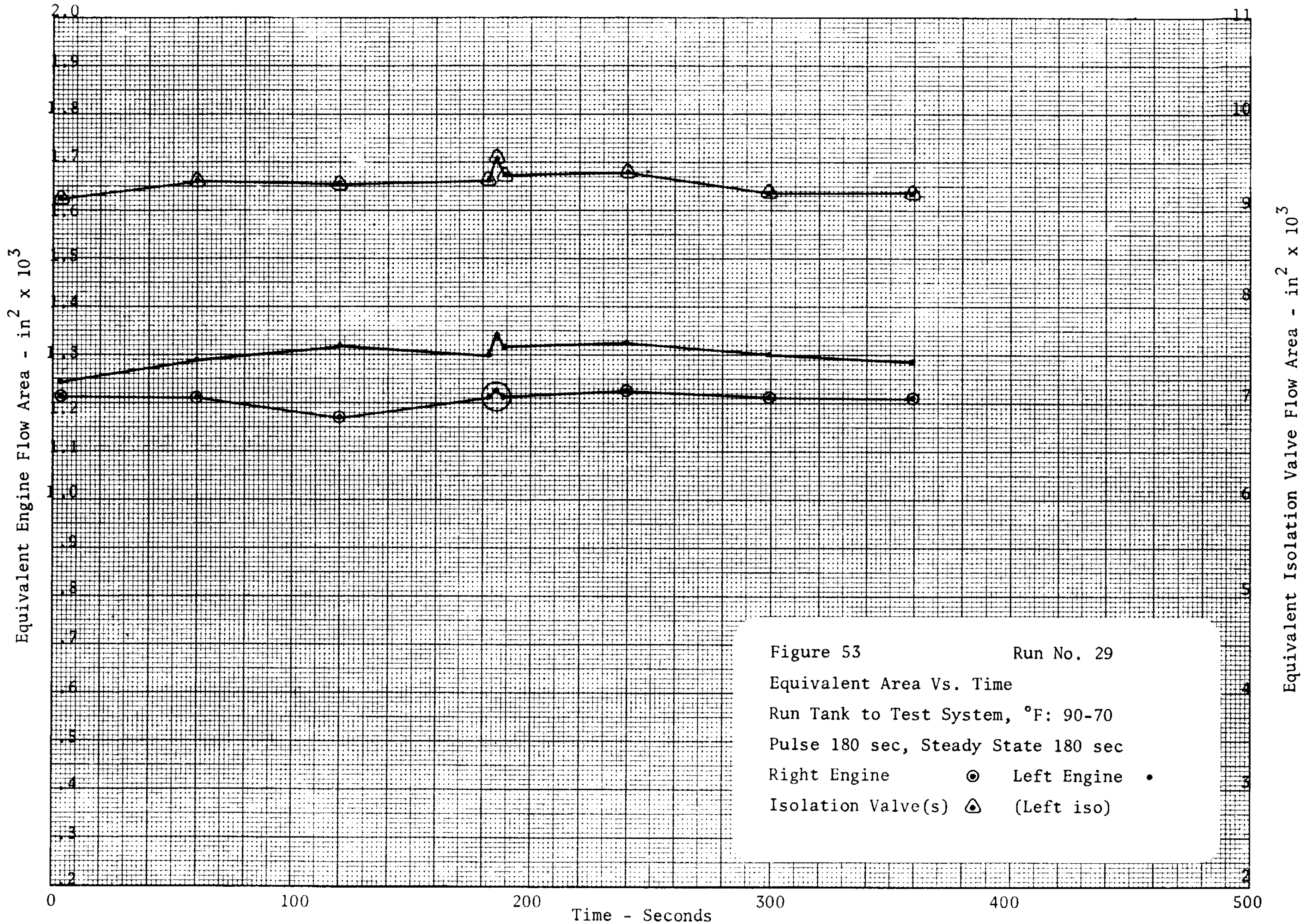

Figure 53 Run No. 29

Equivalent Area Vs. Time

Run Tank to Test System, °F: 90-70

Pulse 180 sec, Steady State 180 sec

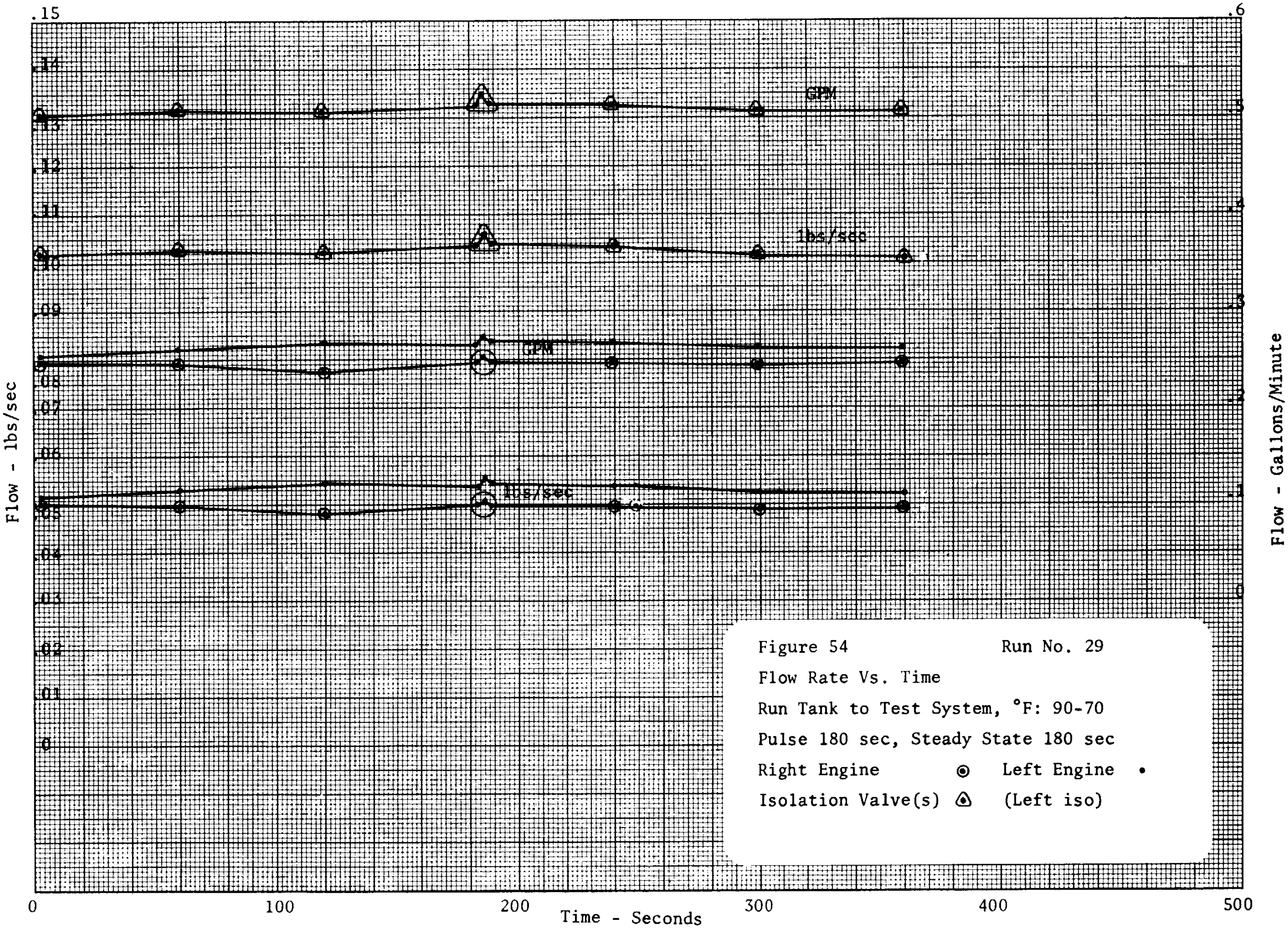
Figure 54 Run No. 29
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-70
Pulse 180 sec, Steady State 180 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) (Left iso)
GPM
lbs/sec
GPM
lbs/sec
Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
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.6
.5
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.3
.2
.1
0
0
100
200
300
400
500

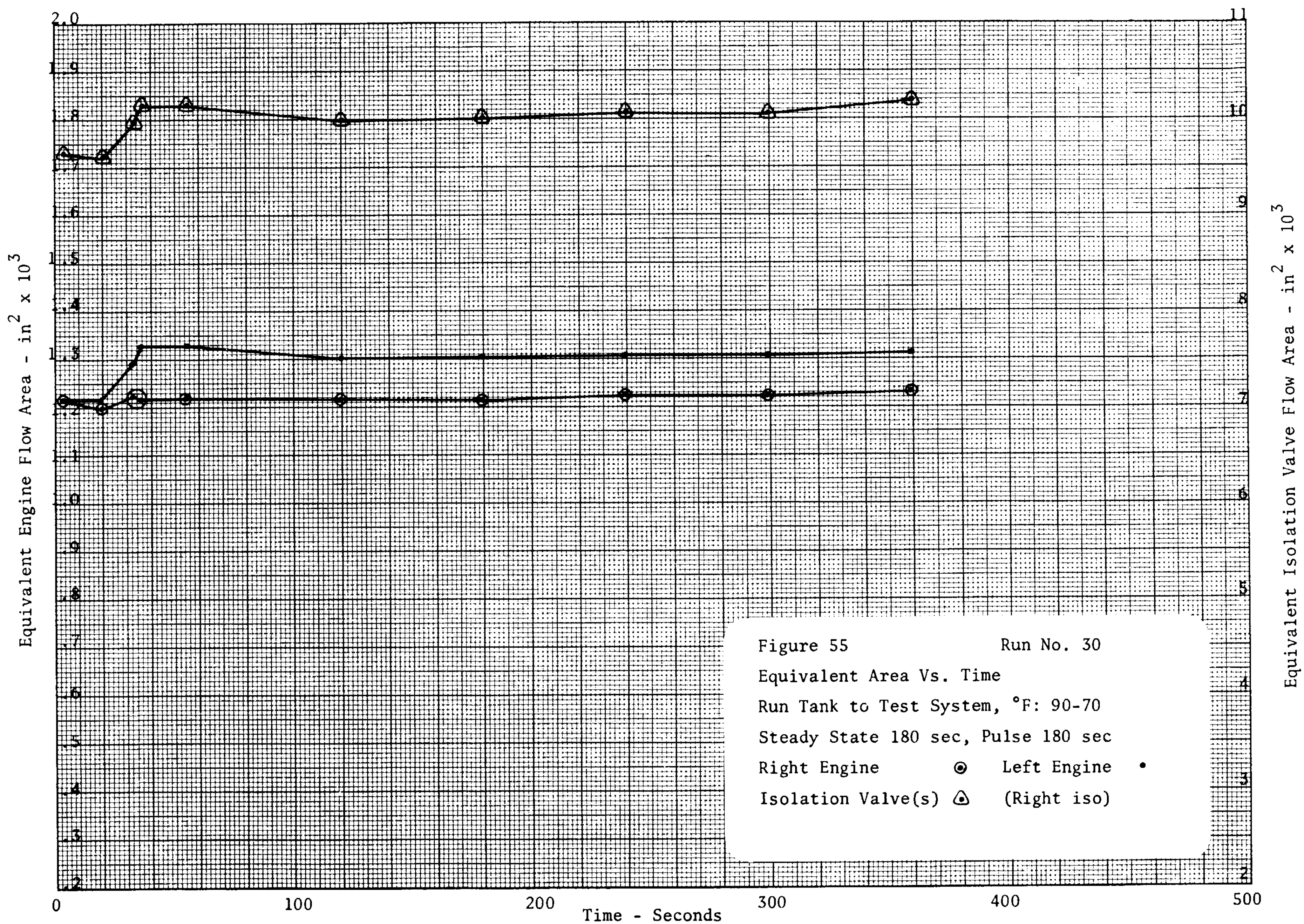


Figure 55 Run No. 30
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-70
Steady State 180 sec, Pulse 180 sec

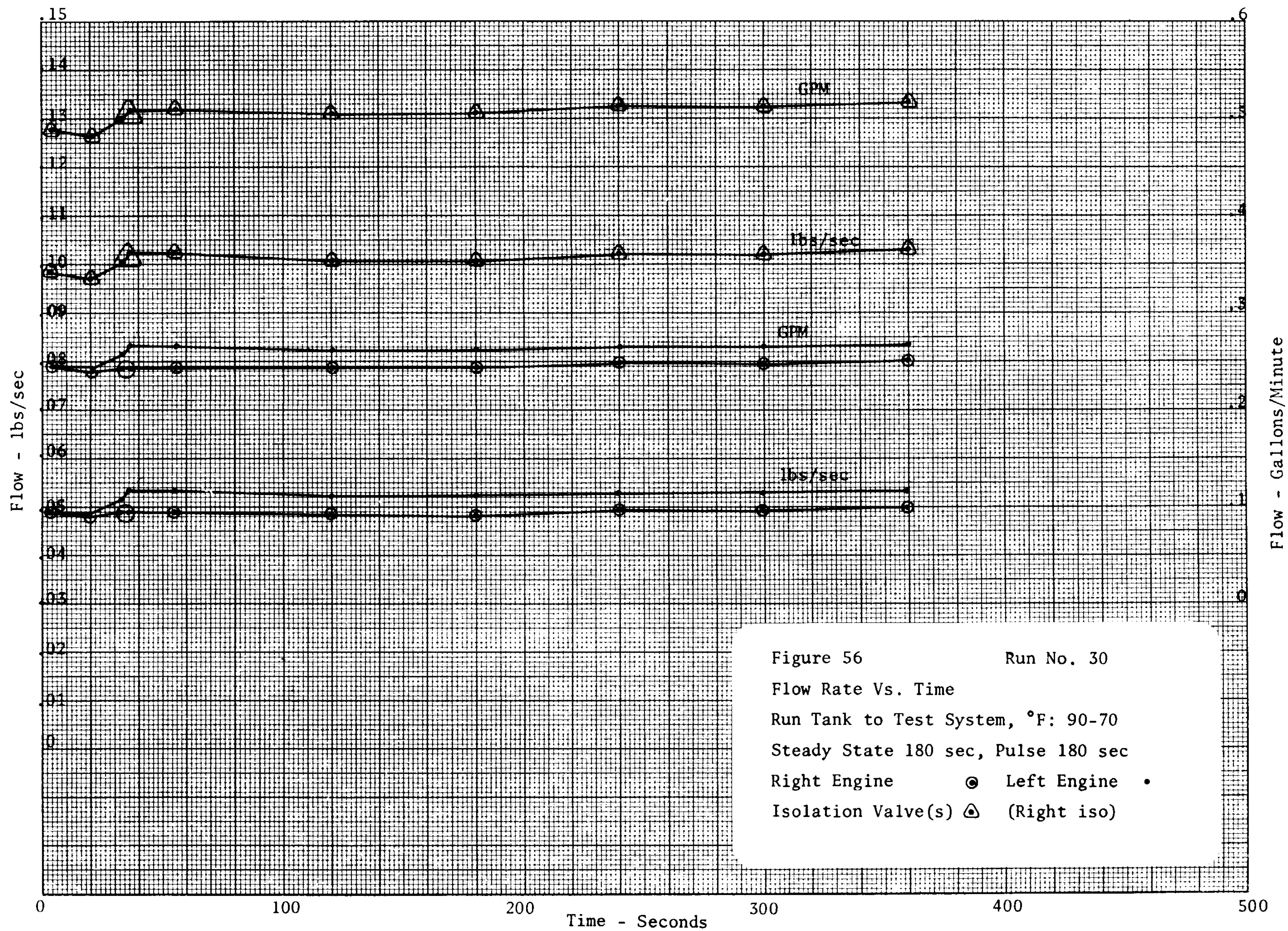


Figure 56 Run No. 30

Flow Rate Vs. Time

Run Tank to Test System, °F: 90-70

Steady State 180 sec, Pulse 180 sec

Right Engine ◉ Left Engine •

Isolation Valve(s) ◬ (Right iso)

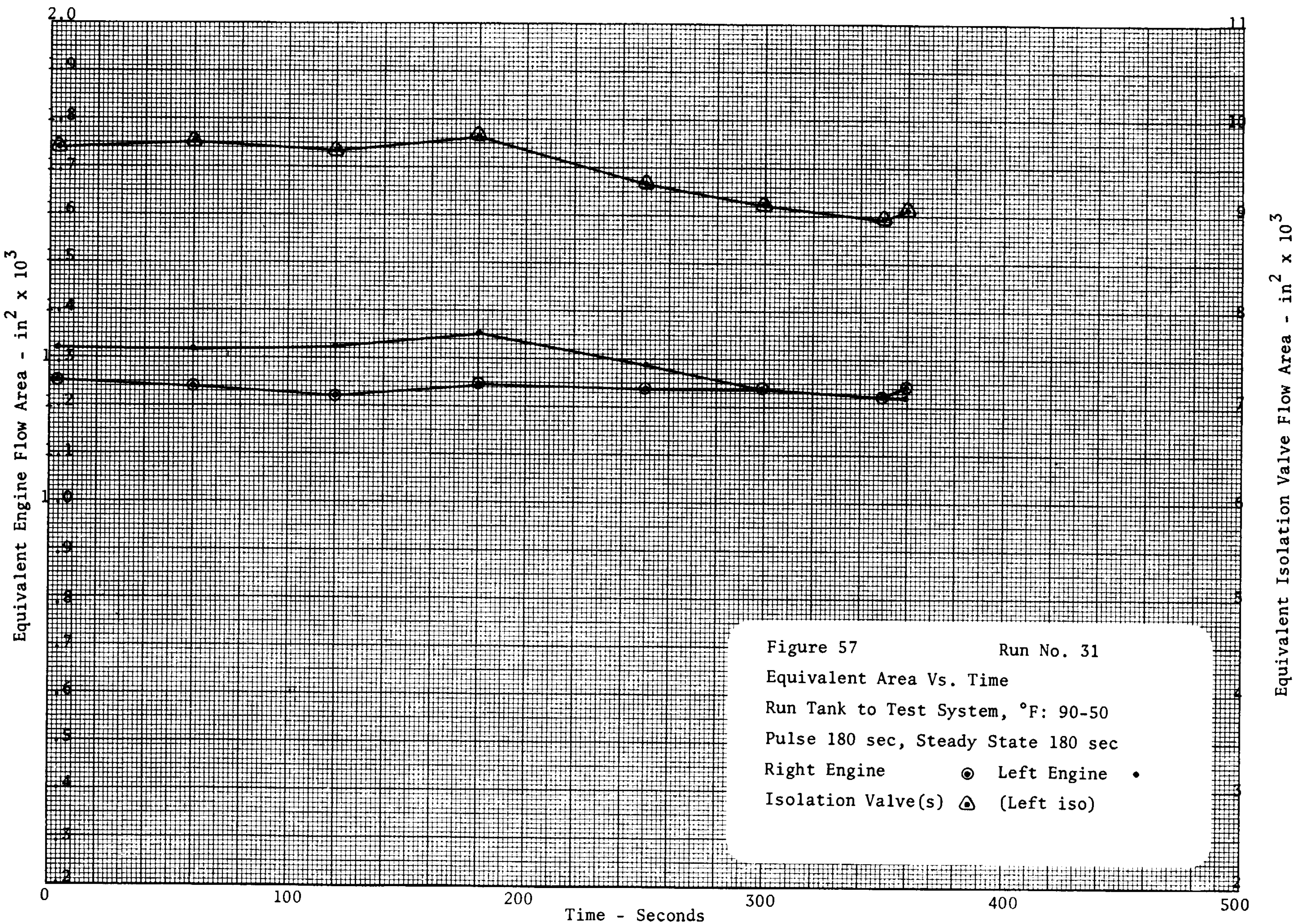
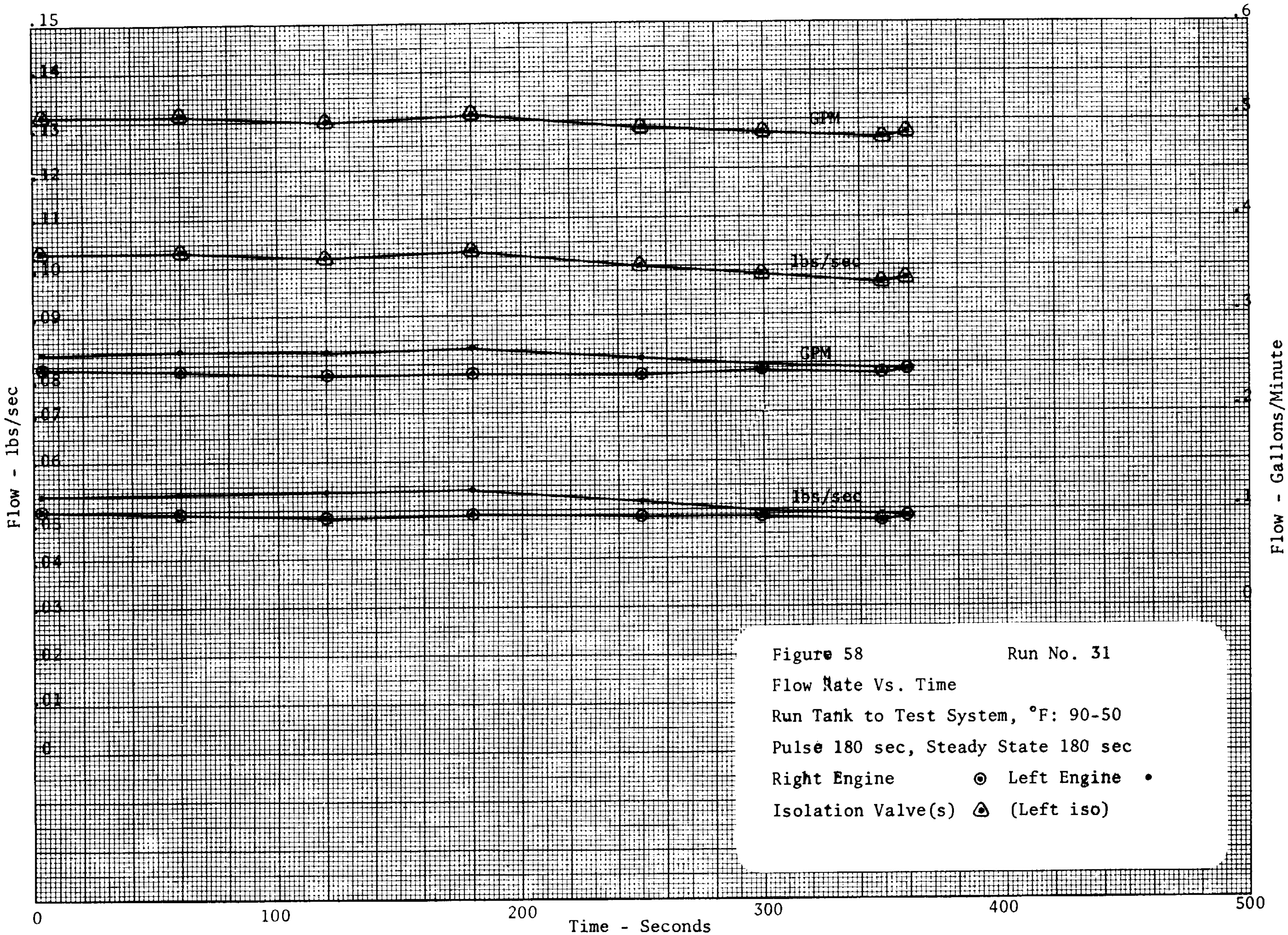


Figure 57
Run No. 31
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-50
Pulse 180 sec, Steady State 180 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Left iso)
Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
2.0
1.0
0
100
200
300
400
500
11
10
9
8
7
6
5
4
3
2



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.07
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.04
.03
.02
.01
0
.6
.5
.4
.3
.2
.1
0
GPM
lbs/sec
GPM
lbs/sec
Flow - lbs/sec
Flow - Gallons/Minute
0
100
200
300
400
500
Time - Seconds
Figure 58 Run No. 31
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-50
Pulse 180 sec, Steady State 180 sec
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Left iso)

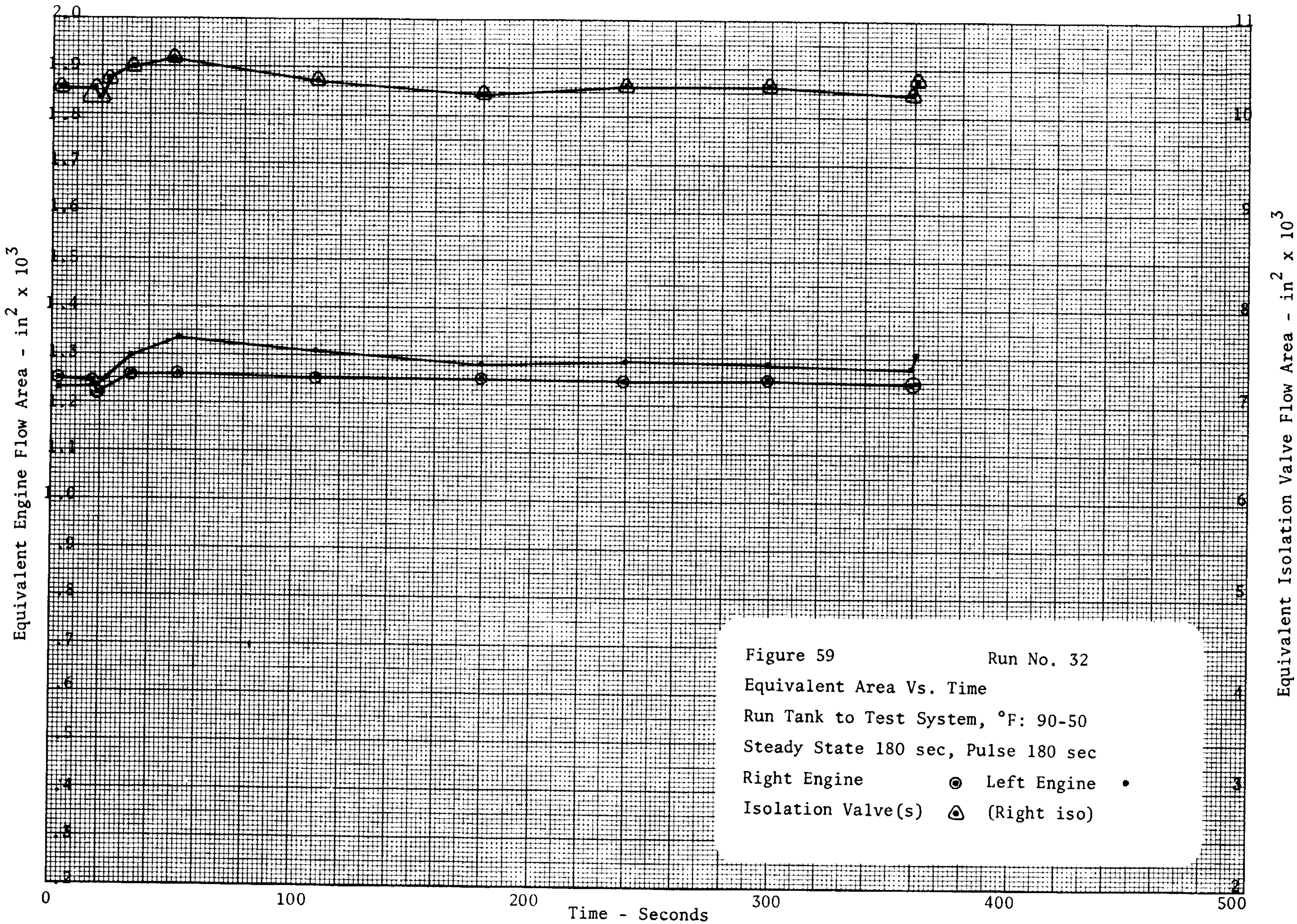


Figure 59
Equivalent Area Vs. Time

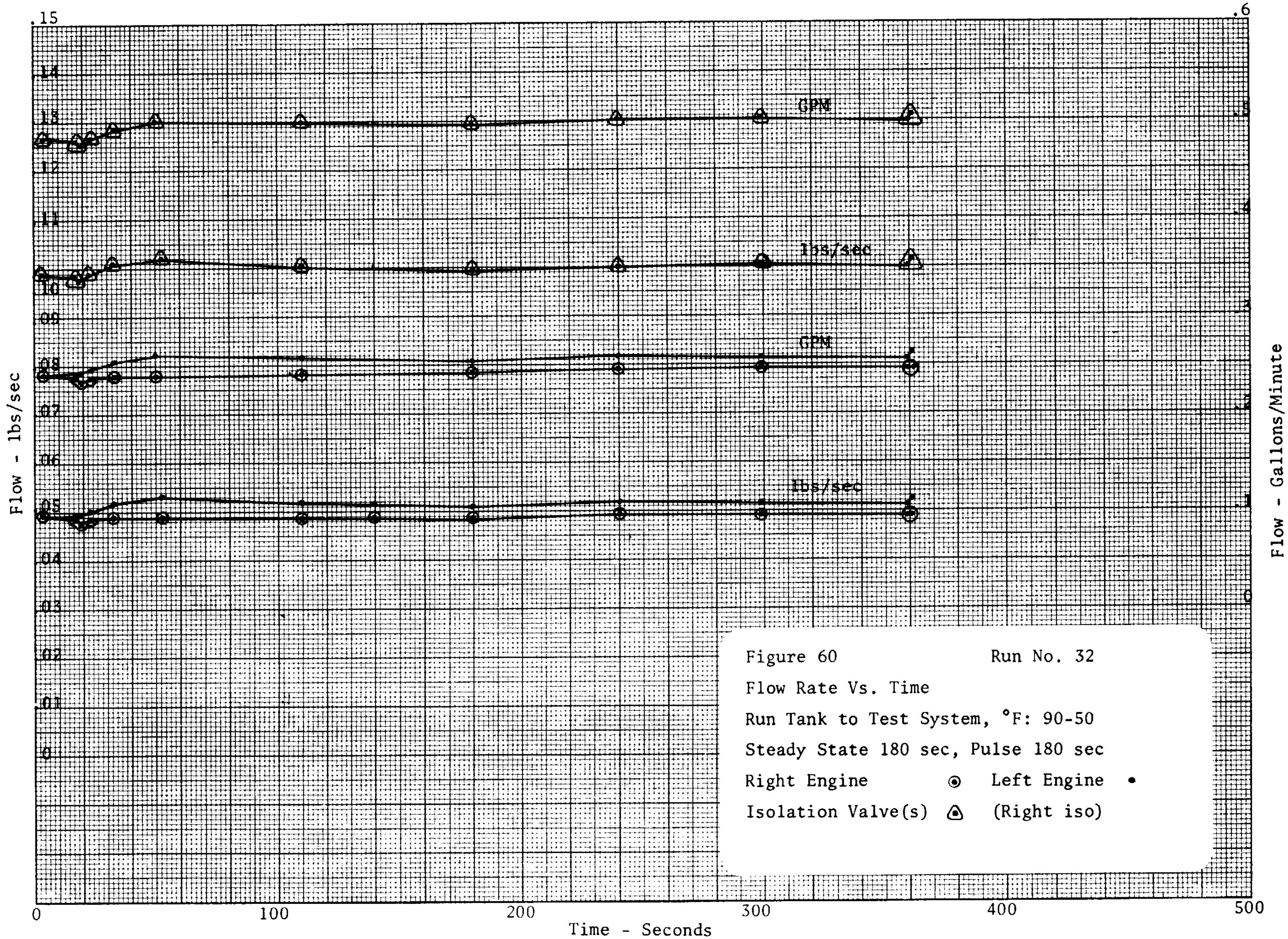


Figure 60 Run No. 32

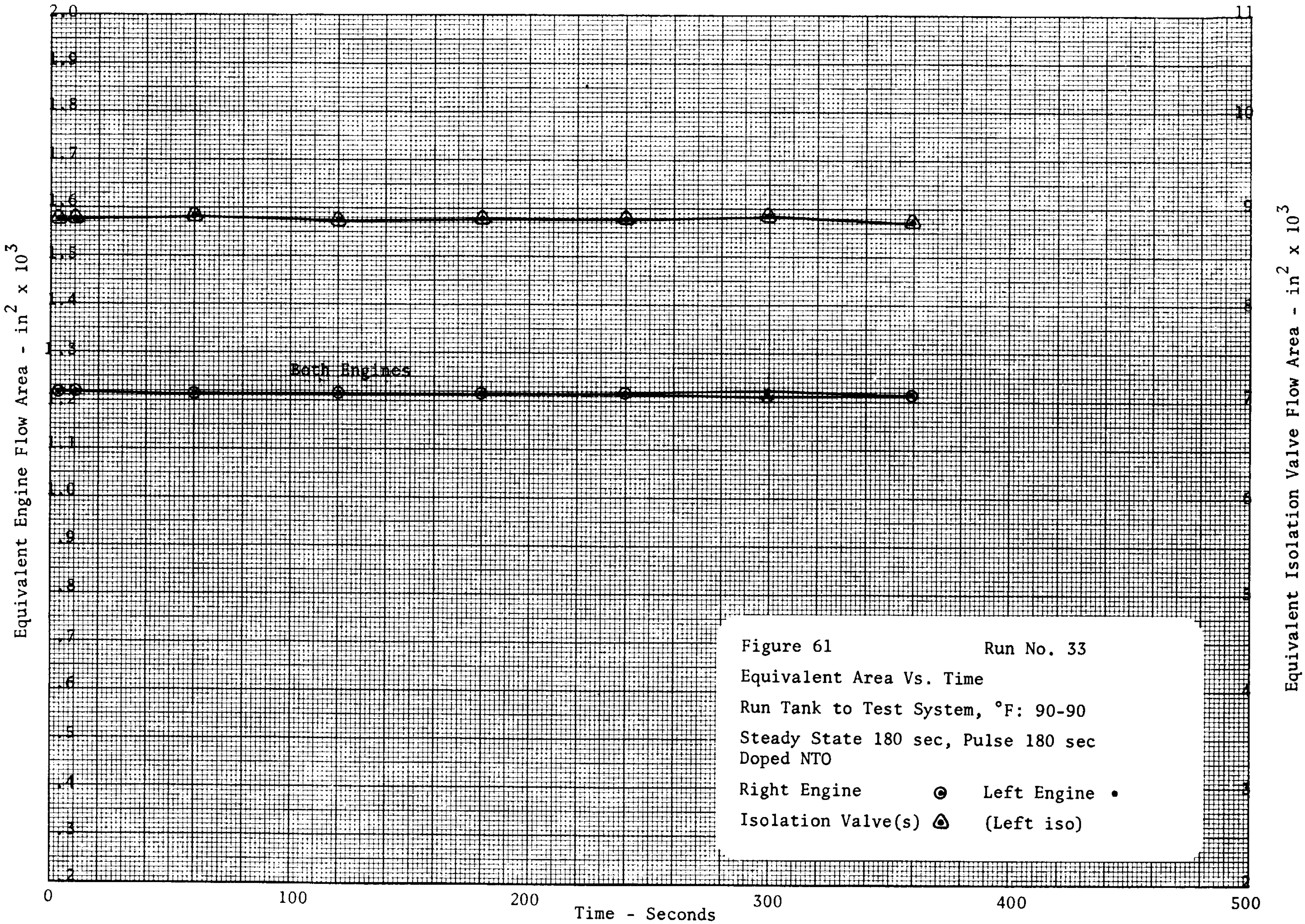
Flow Rate Vs. Time

Run Tank to Test System, °F: 90-50

Steady State 180 sec, Pulse 180 sec

Right Engine ⊙ Left Engine •

Isolation Valve(s) △ (Right iso)



Equivalent Engine Flow Area - $in^2 \times 10^3$
Equivalent Isolation Valve Flow Area - $in^2 \times 10^3$
Time - Seconds
Both Engines
Figure 61
Run No. 33
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-90
Steady State 180 sec, Pulse 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)

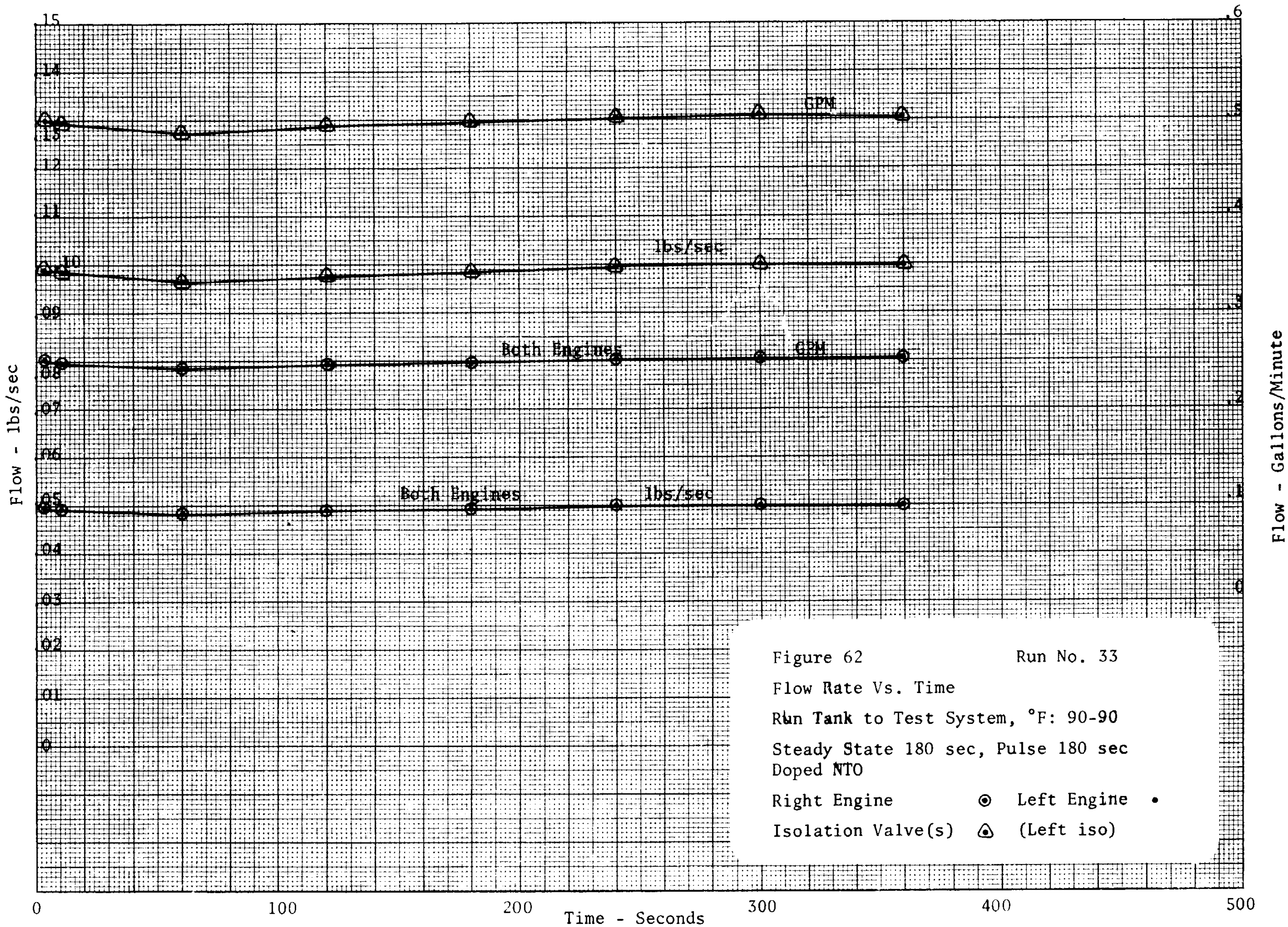
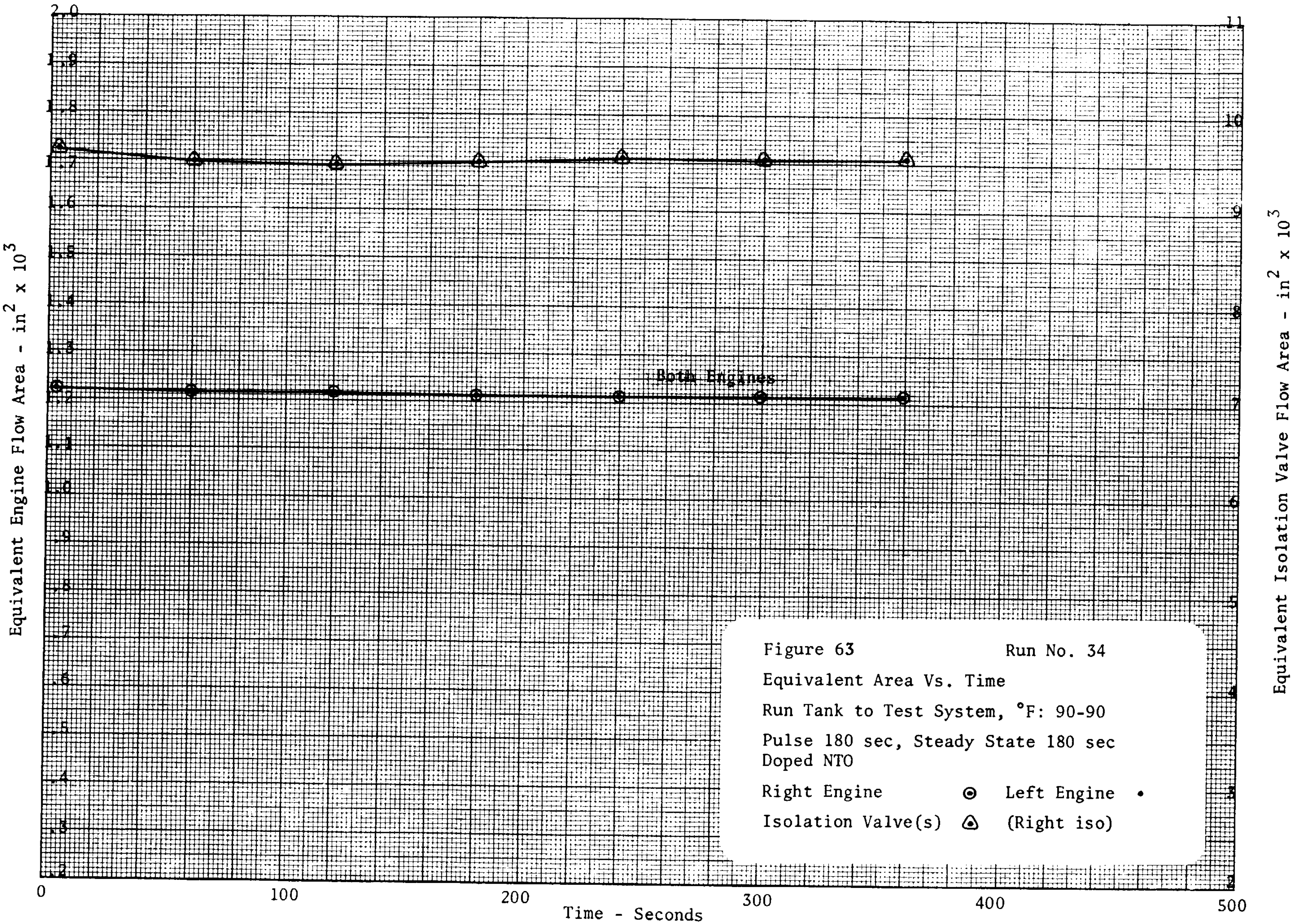
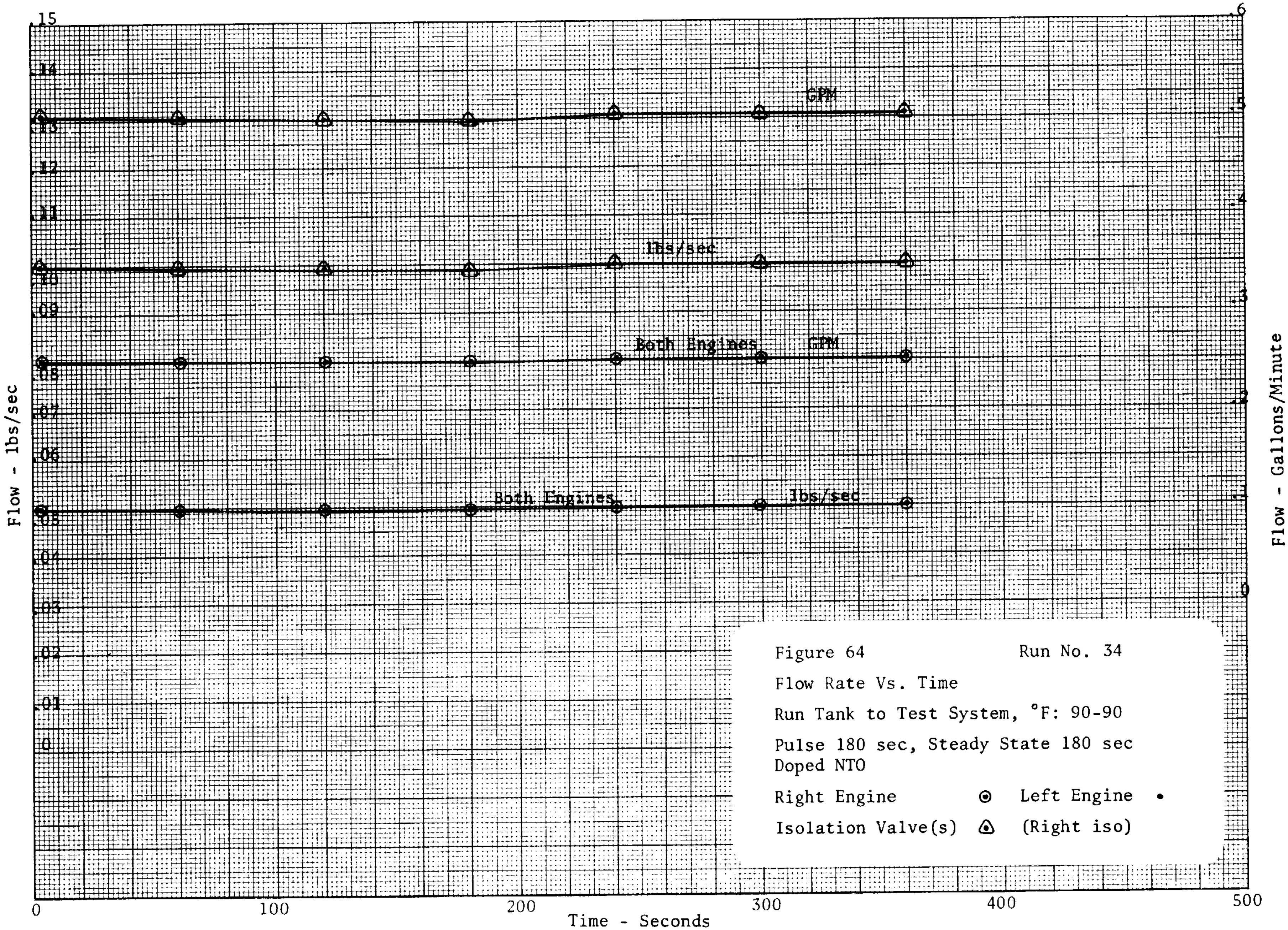


Figure 62
Run No. 33
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-90
Steady State 180 sec, Pulse 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)
GPM
lbs/sec
Both Engines
GPM
Both Engines
lbs/sec
Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
0
100
200
300
400
500



Equivalent Engine Flow Area - in^2 x 10^3
Equivalent Isolation Valve Flow Area - in^2 x 10^3
Time - Seconds
0
100
200
300
400
500
Both Engines
Figure 63
Run No. 34
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-90
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)



.15
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.06
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.04
.03
.02
.01
0
Flow - lbs/sec
.6
.5
.4
.3
.2
.1
0
Flow - Gallons/Minute
0
100
200
300
400
500
Time - Seconds
GPM
lbs/sec
Both Engines
GPM
Both Engines
lbs/sec
Figure 64
Run No. 34
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-90
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine ⊙
Left Engine •
Isolation Valve(s) △
(Right iso)

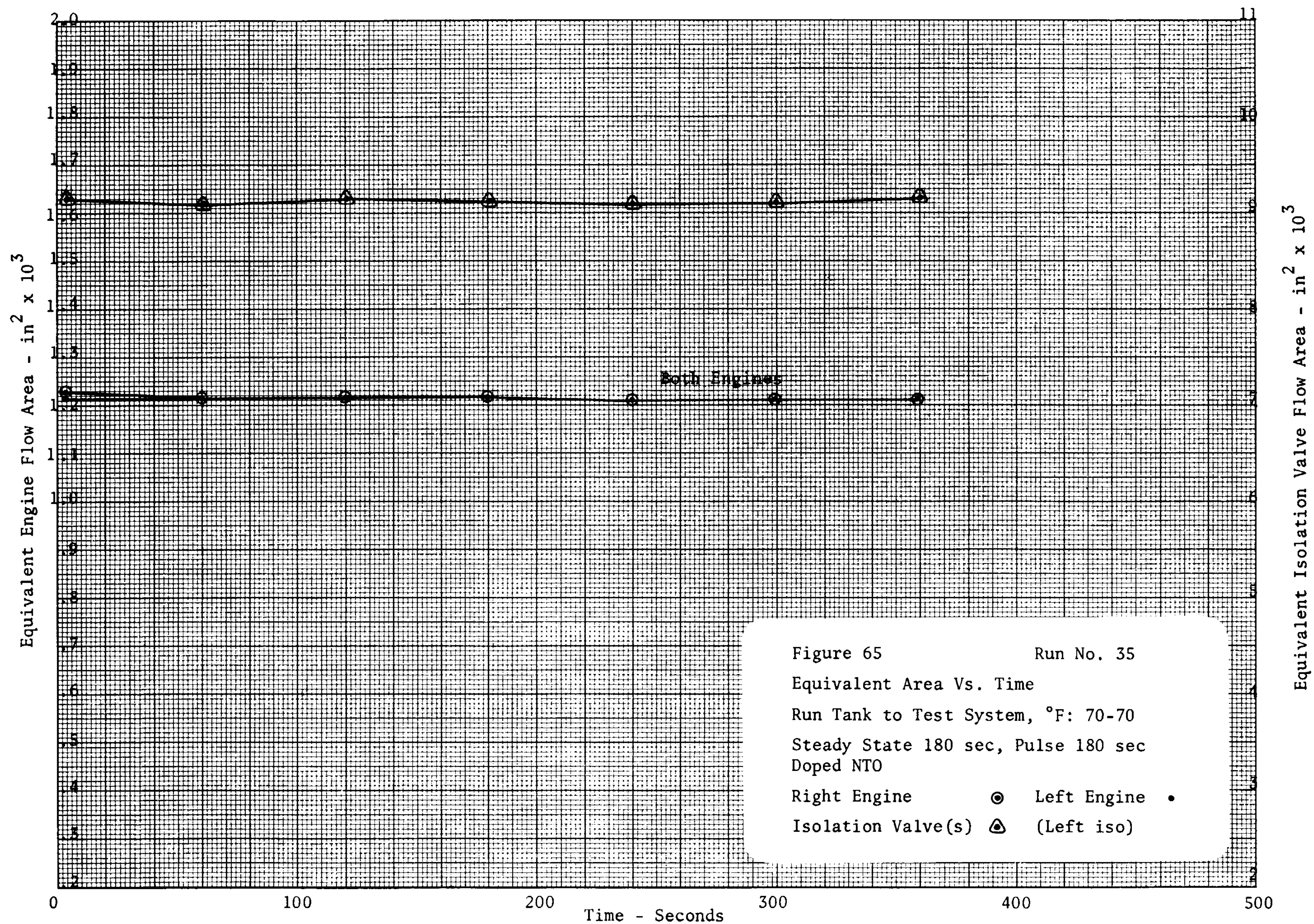


Figure 65 Run No. 35

Equivalent Area Vs. Time

Run Tank to Test System, °F: 70-70

Steady State 180 sec, Pulse 180 sec

Doped NTO

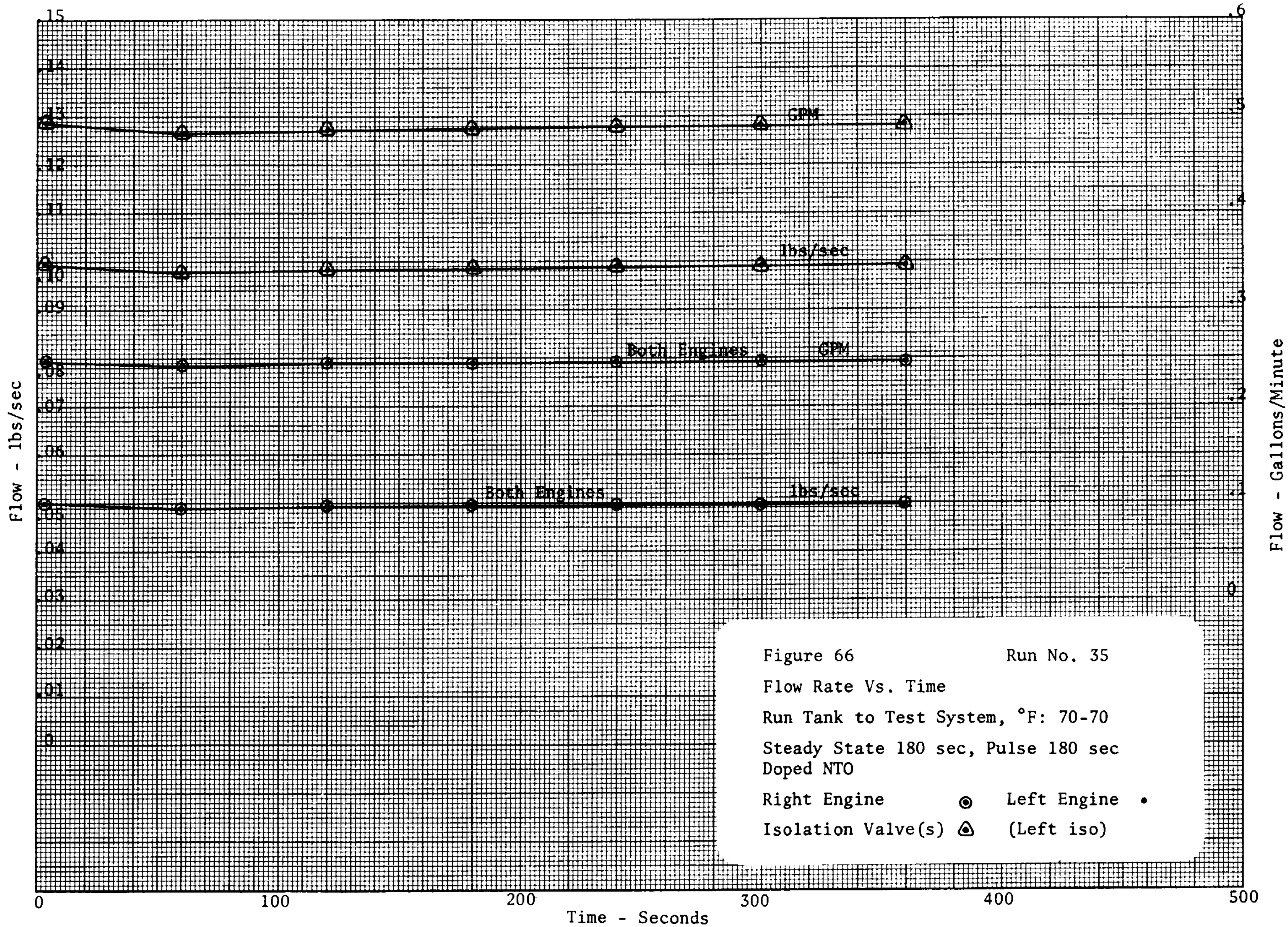


Figure 66 Run No. 35

Flow Rate Vs. Time

Run Tank to Test System, °F: 70-70

Steady State 180 sec, Pulse 180 sec
Doped NTO

Right Engine ◉ Left Engine •

Isolation Valve(s) △ (Left iso)

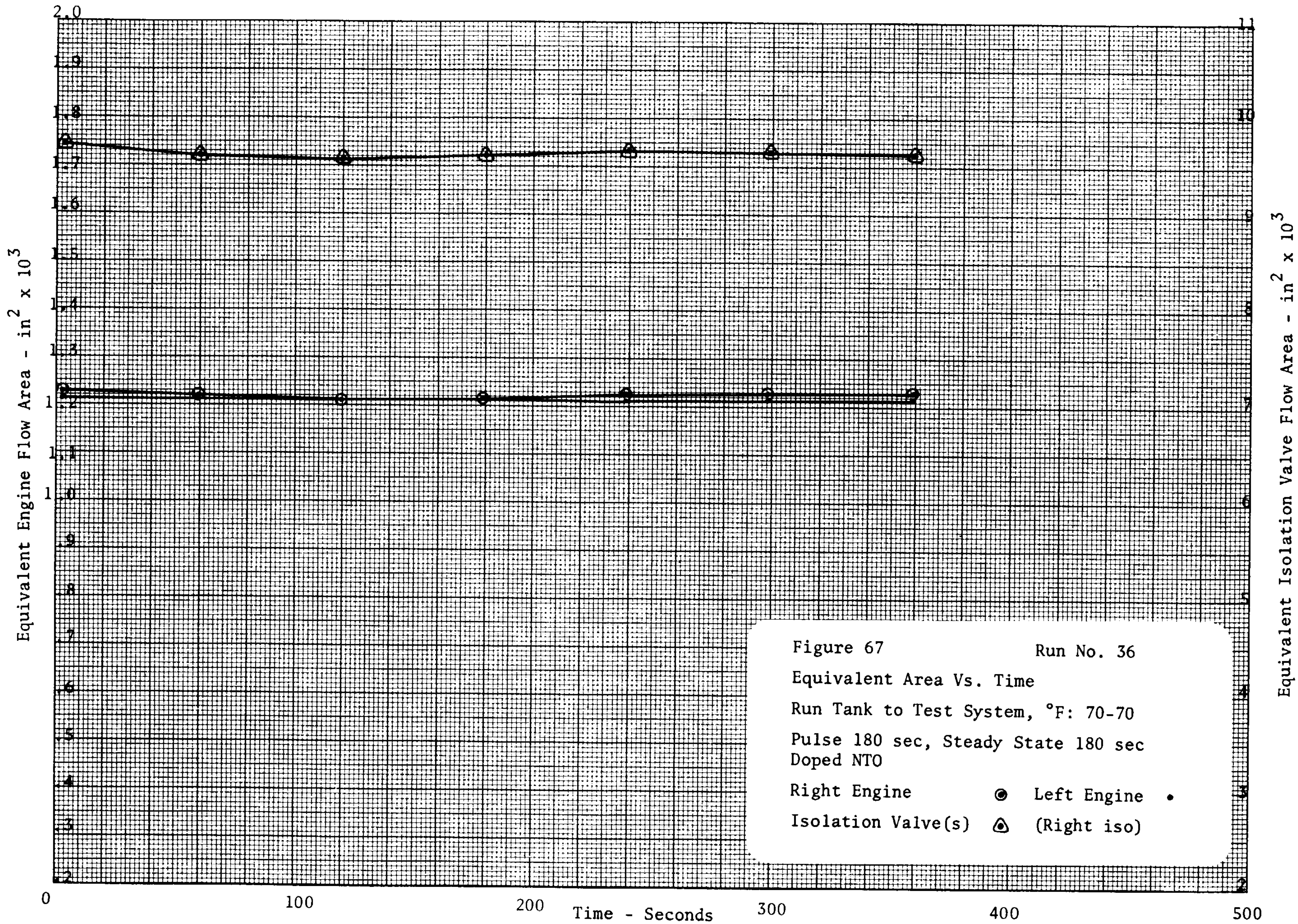
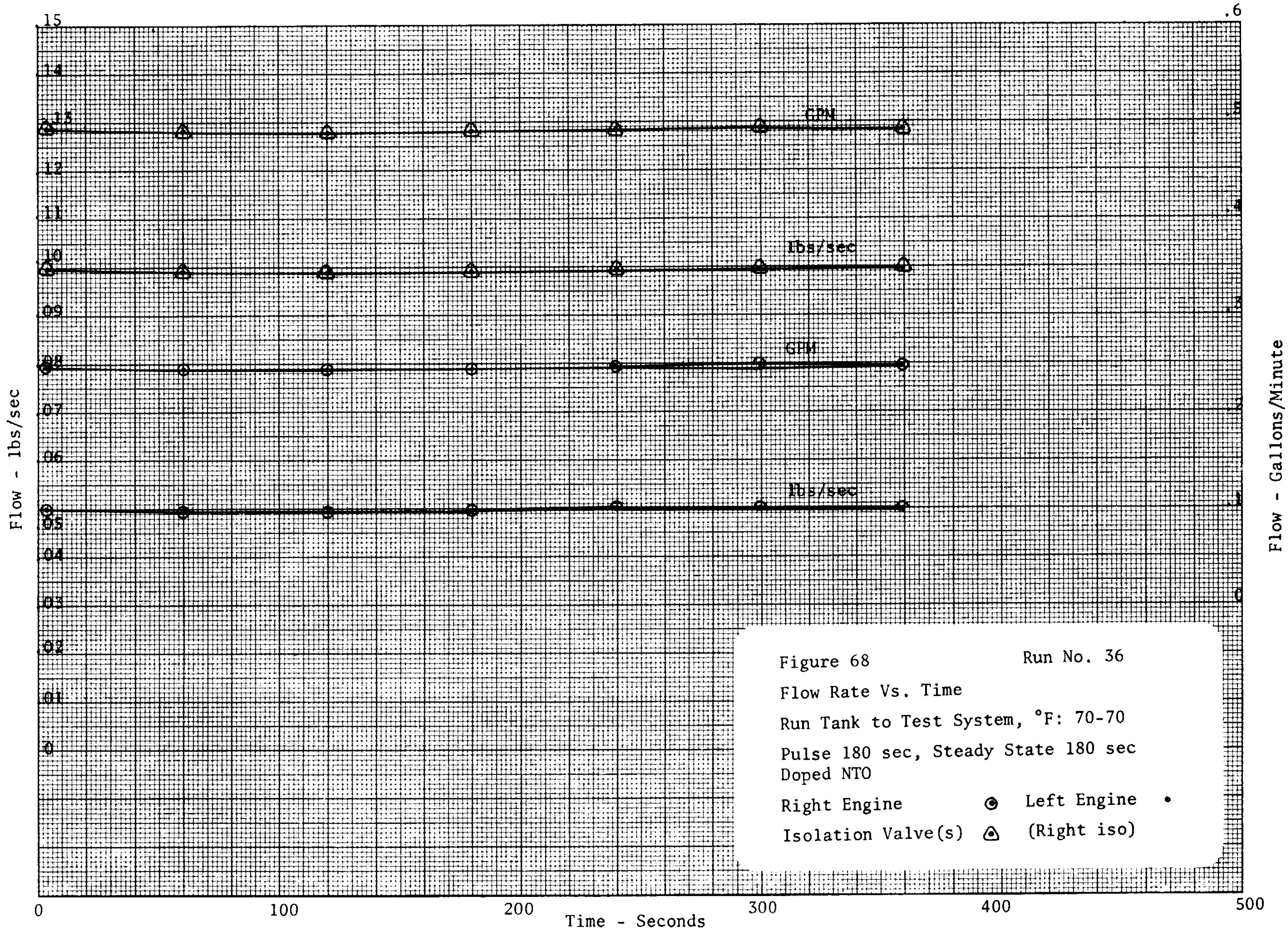
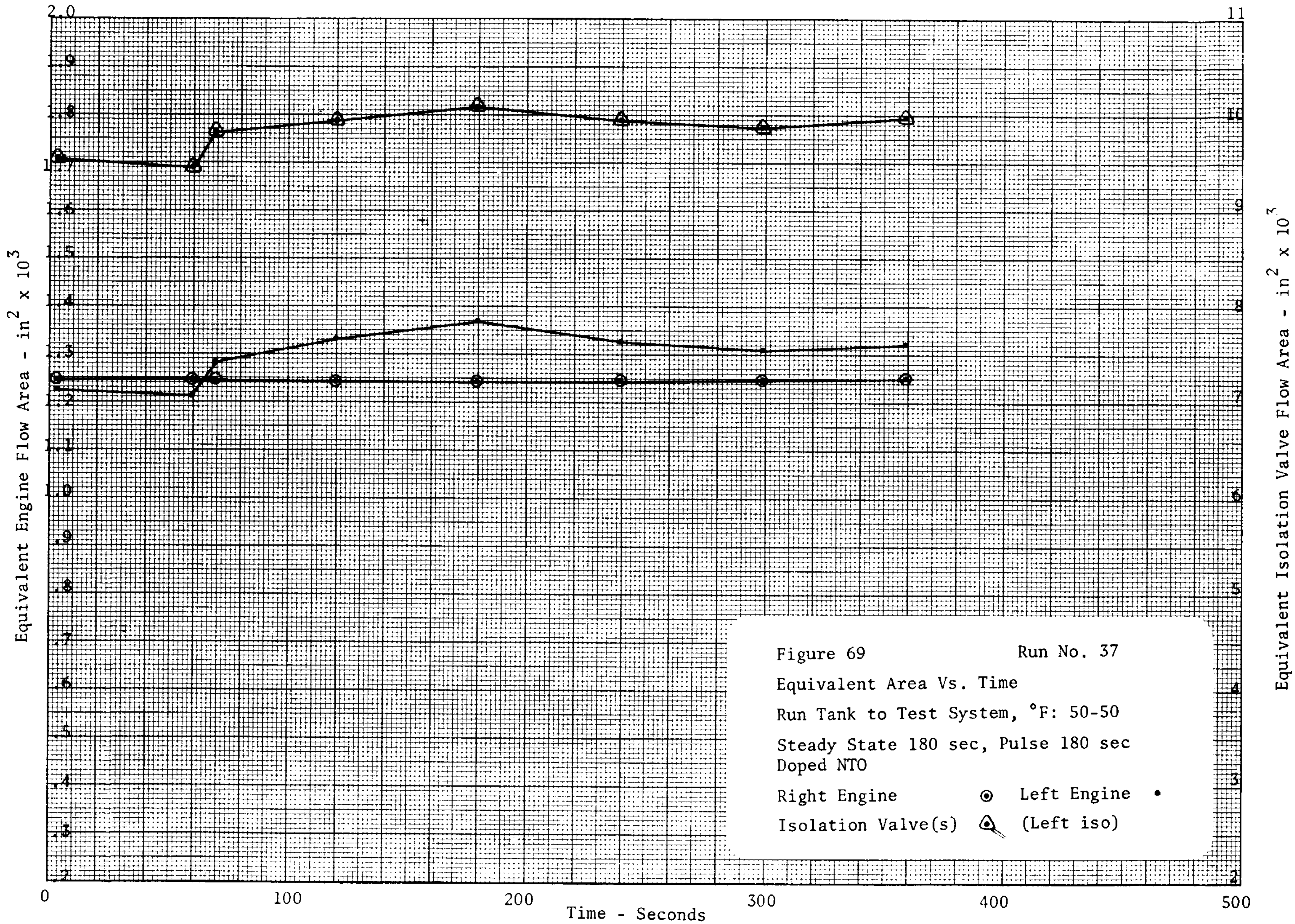


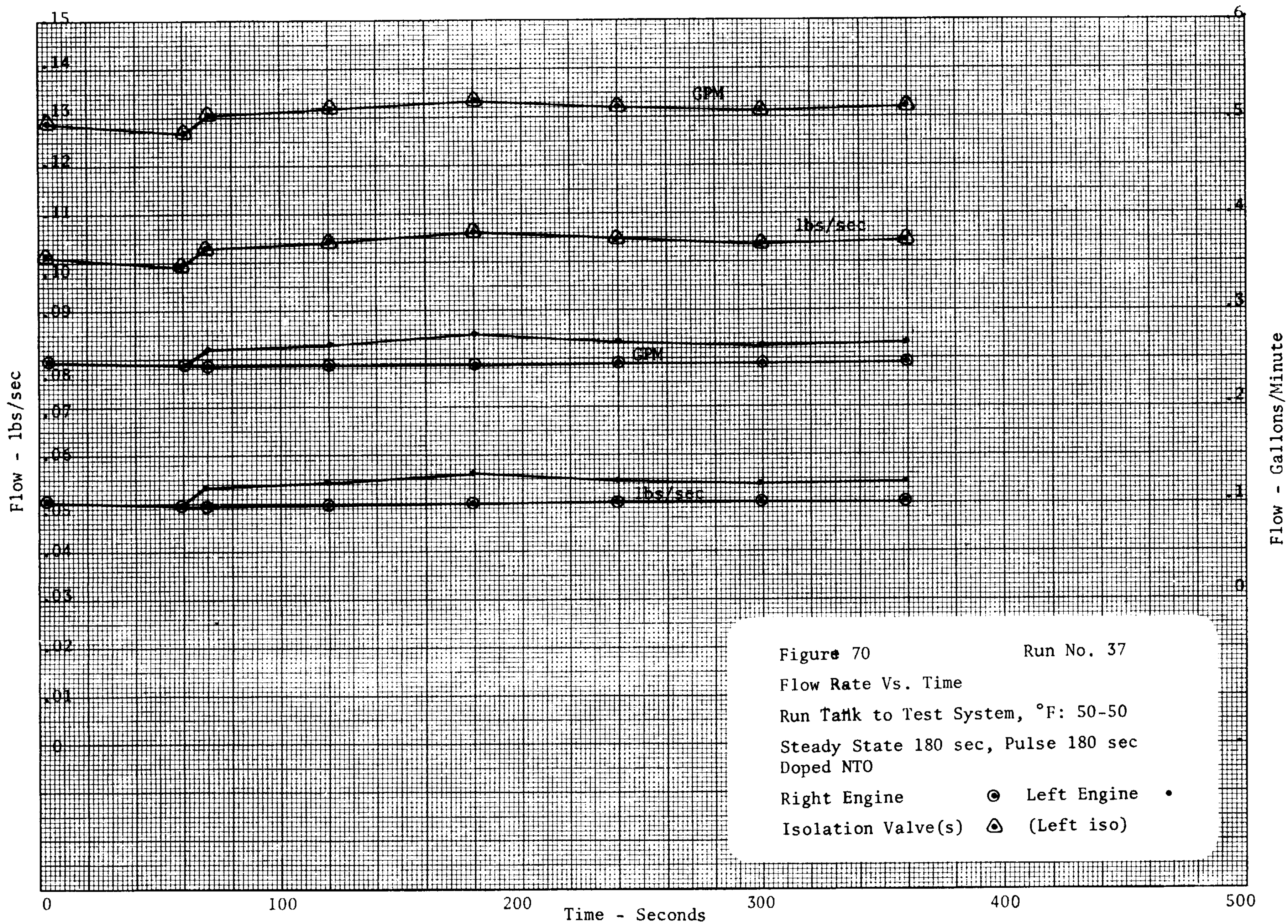
Figure 67
Run No. 36
Equivalent Area Vs. Time
Run Tank to Test System, °F: 70-70
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)
Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2



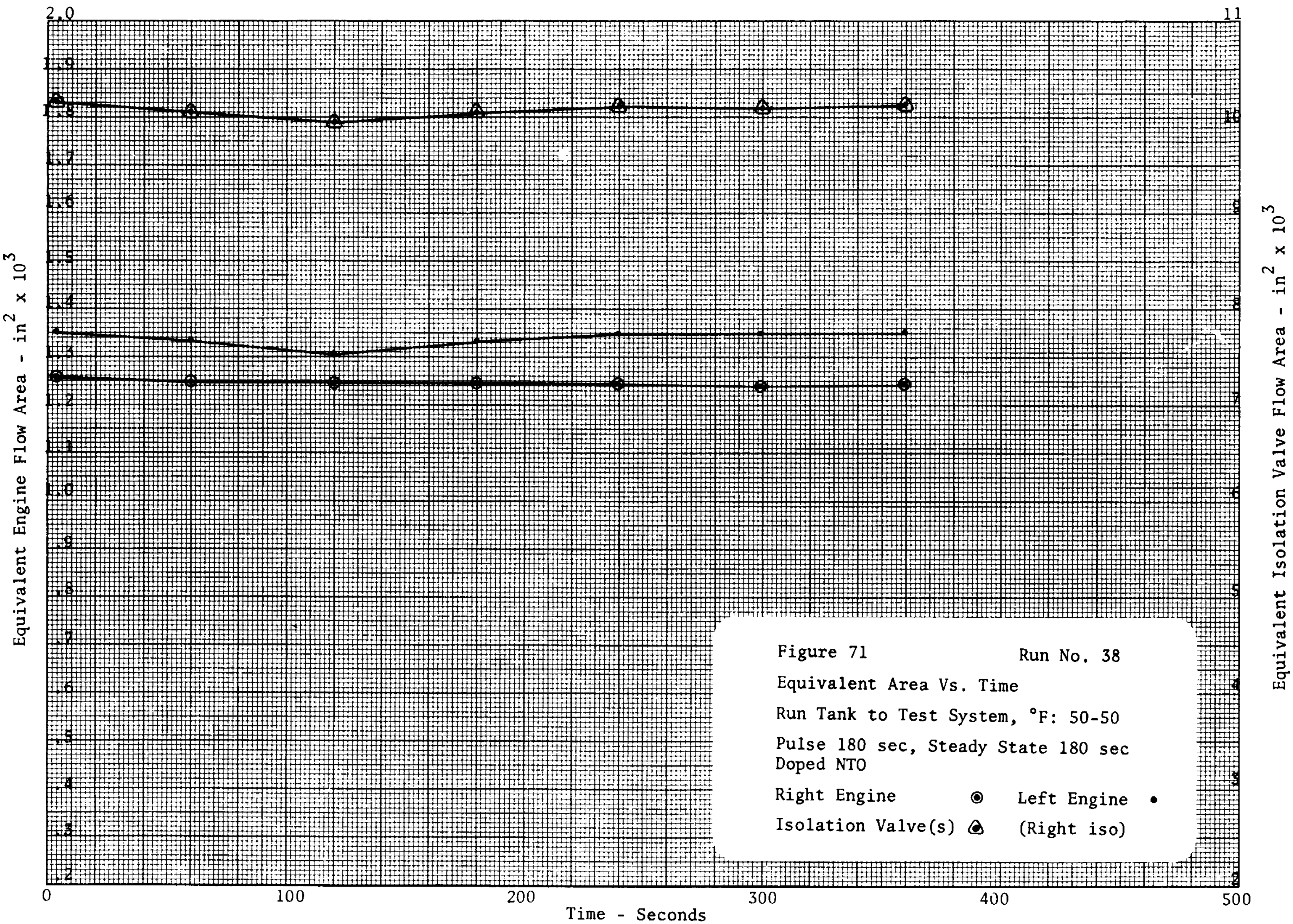
Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
0
100
200
300
400
500
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
.6
.5
.4
.3
.2
.1
0
GPM
lbs/sec
GPM
lbs/sec
Figure 68
Run No. 36
Flow Rate Vs. Time
Run Tank to Test System, °F: 70-70
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)



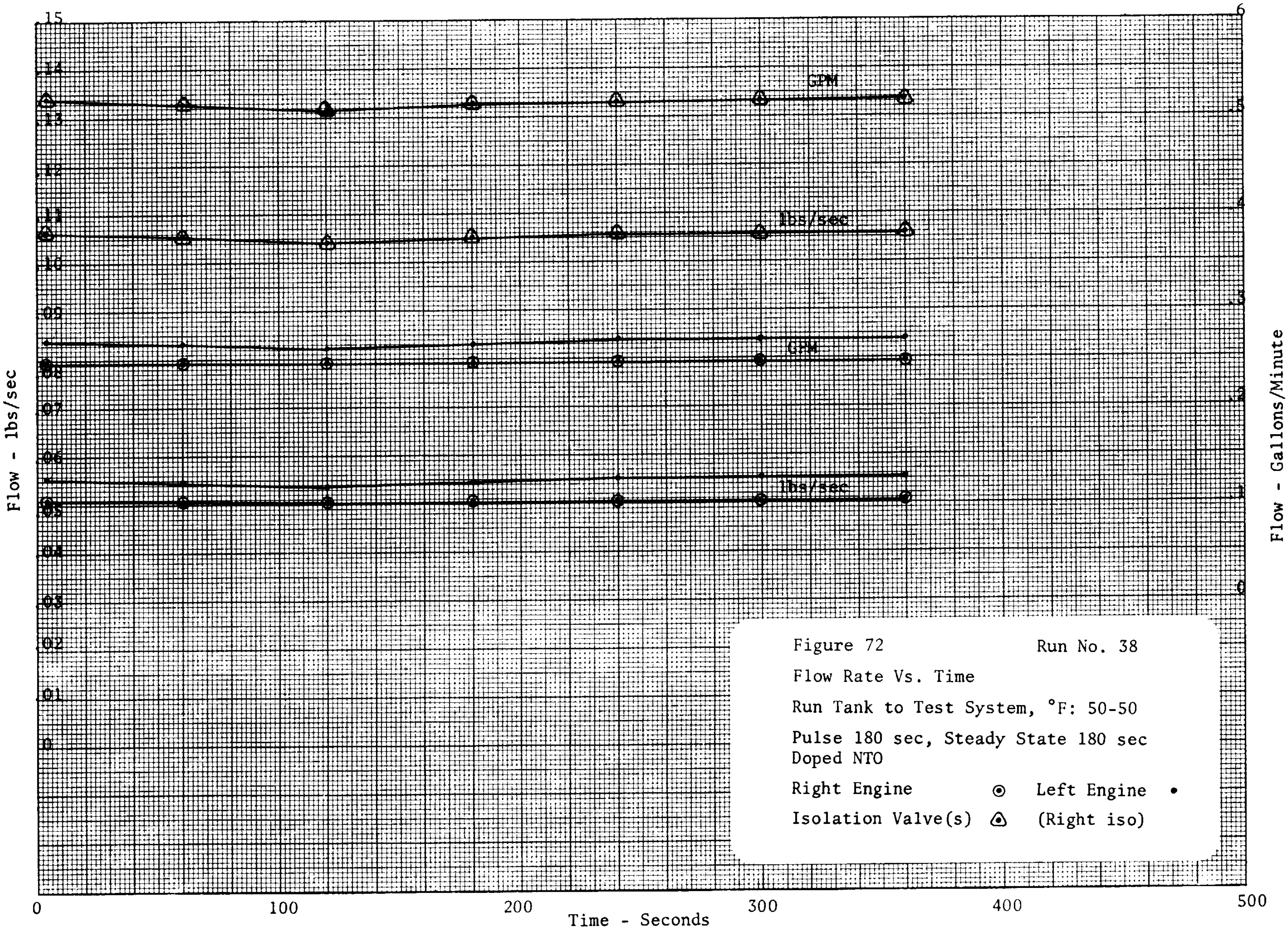
Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2
Figure 69
Run No. 37
Equivalent Area Vs. Time
Run Tank to Test System, °F: 50-50
Steady State 180 sec, Pulse 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)

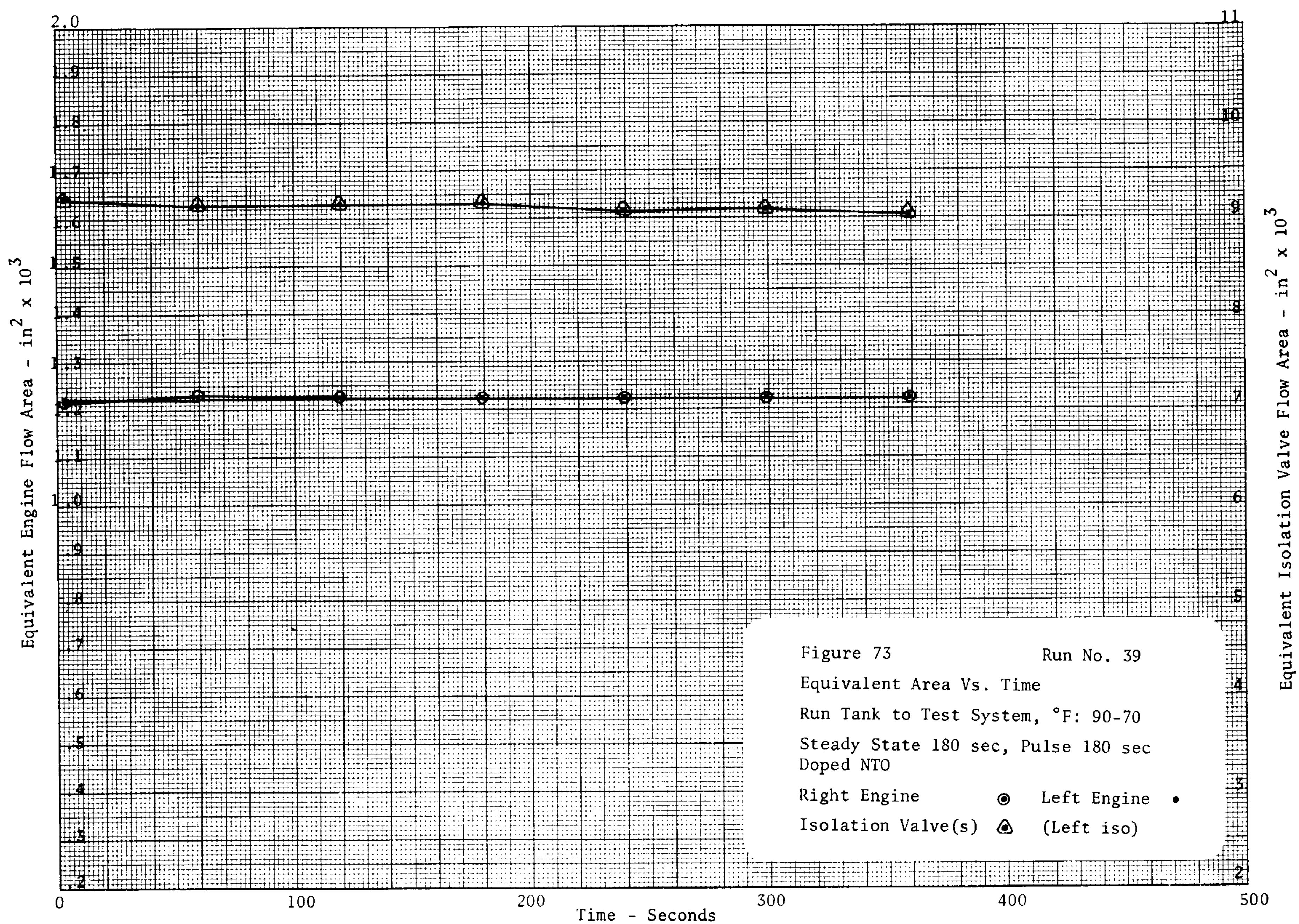


Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
GPM
lbs/sec
GPM
lbs/sec
Figure 70
Run No. 37
Flow Rate Vs. Time
Run Tank to Test System, °F: 50-50
Steady State 180 sec, Pulse 180 sec
Doped NTO
Right Engine ⊙ Left Engine •
Isolation Valve(s) (Left iso)



Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2
Figure 71
Run No. 38
Equivalent Area Vs. Time
Run Tank to Test System, °F: 50-50
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)


Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
GPM
lbs/sec
GPM
lbs/sec
Figure 72 Run No. 38
Flow Rate Vs. Time
Run Tank to Test System, °F: 50-50
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine ⊙ Left Engine •
Isolation Valve(s) (Right iso)


Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
Figure 73
Run No. 39
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-70
Steady State 180 sec, Pulse 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)

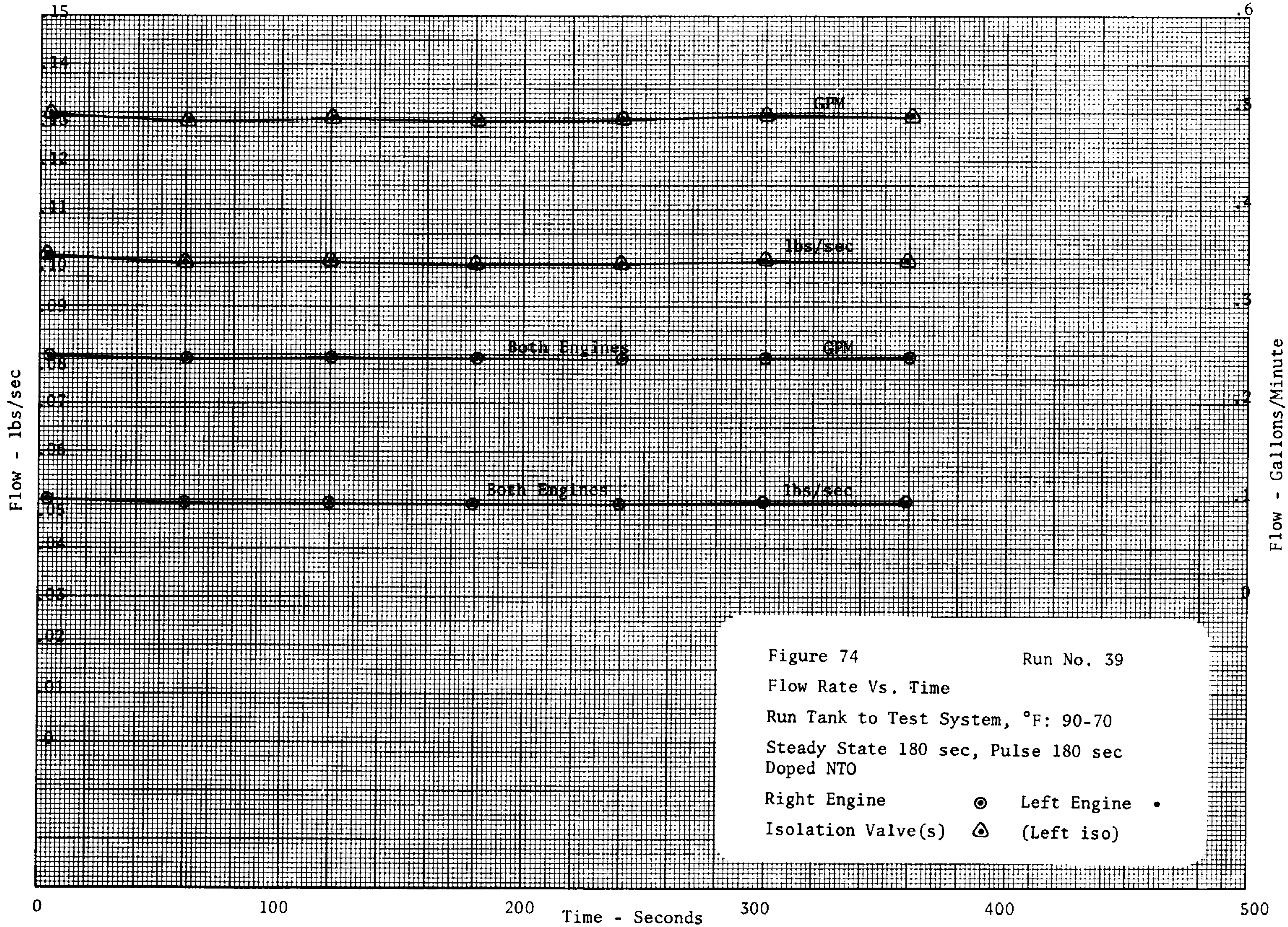


Figure 74 Run No. 39

Flow Rate Vs. Time

Run Tank to Test System, °F: 90-70

Steady State 180 sec, Pulse 180 sec
Doped NTO

Right Engine ◉ Left Engine •

Isolation Valve(s) △ (Left iso)

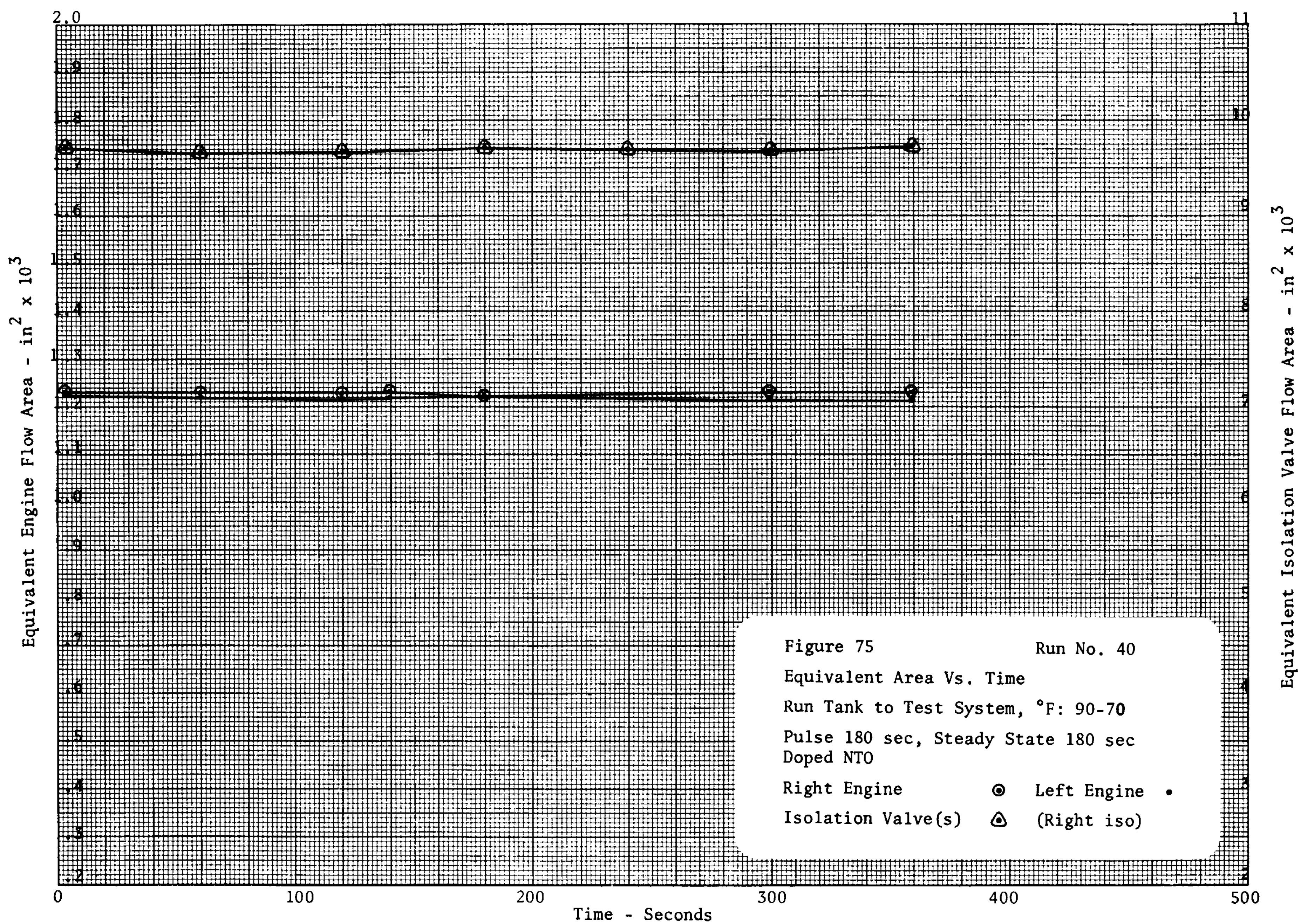


Figure 75
Run No. 40
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-70
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)
Equivalent Engine Flow Area - in² x 10³
Equivalent Isolation Valve Flow Area - in² x 10³
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
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6
5
4
3
2

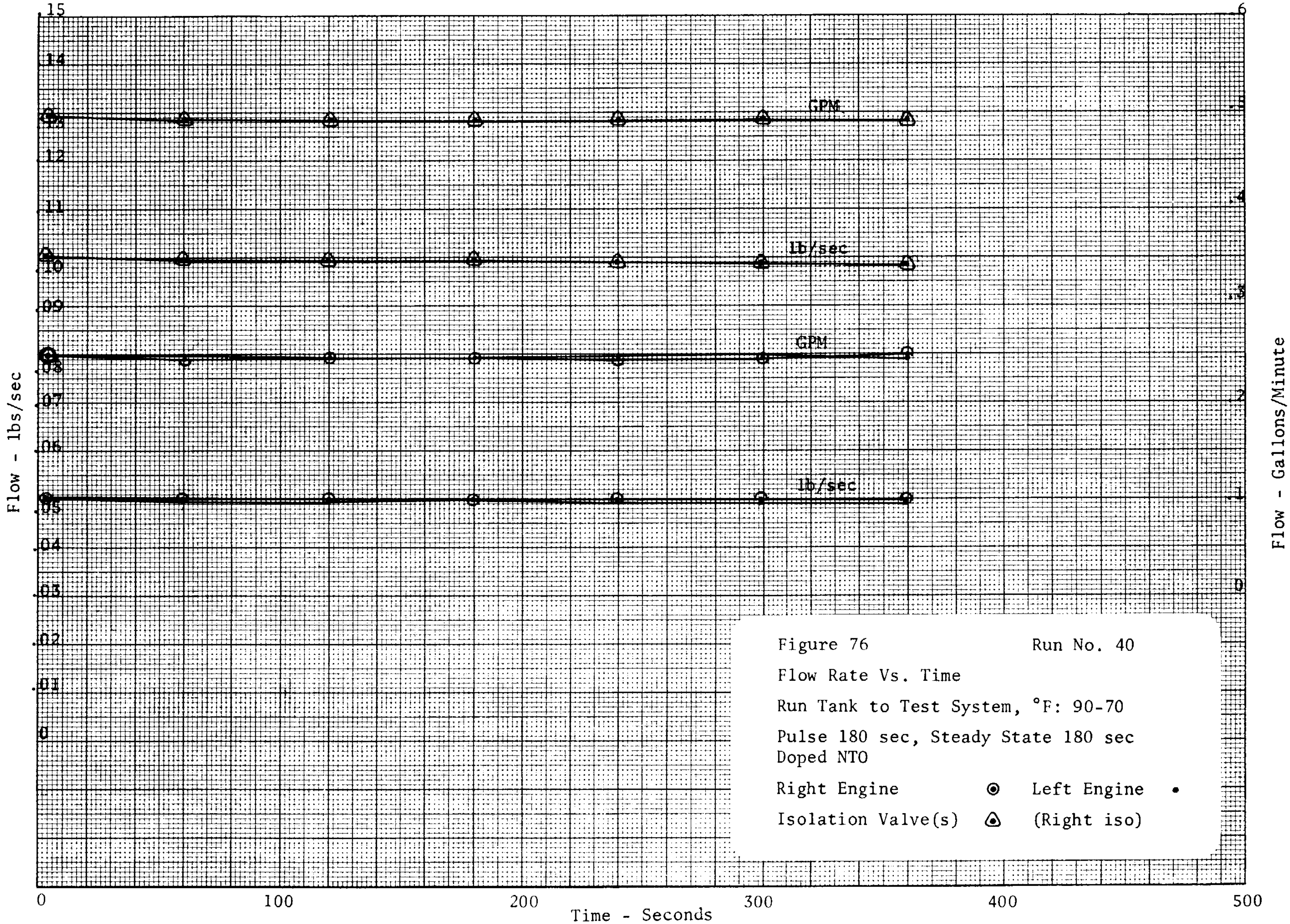


Figure 76
Run No. 40
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-70
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)
GPM
lb/sec
GPM
lb/sec
Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
0
100
200
300
400
500
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
.6
.5
.4
.3
.2
.1
0

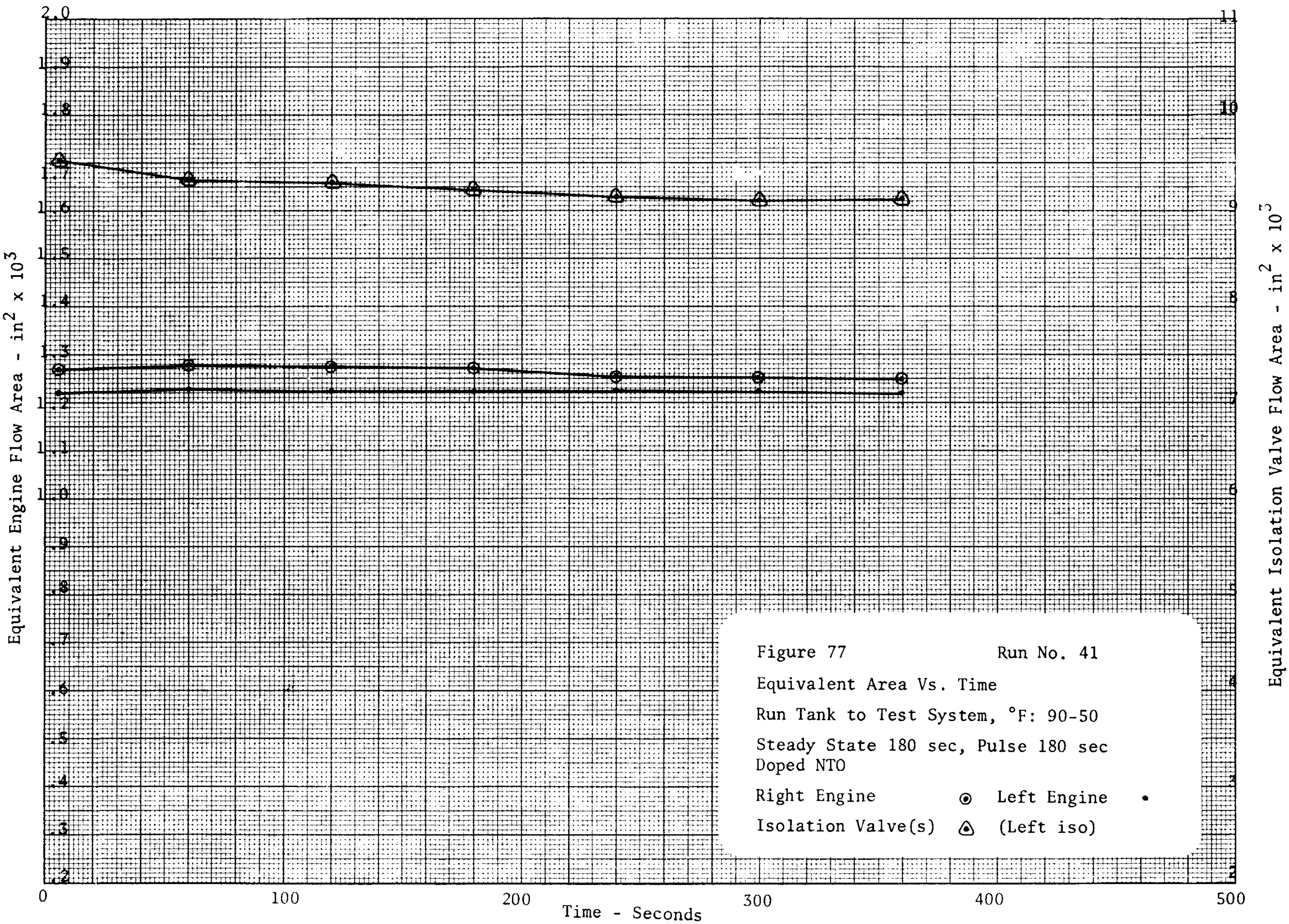
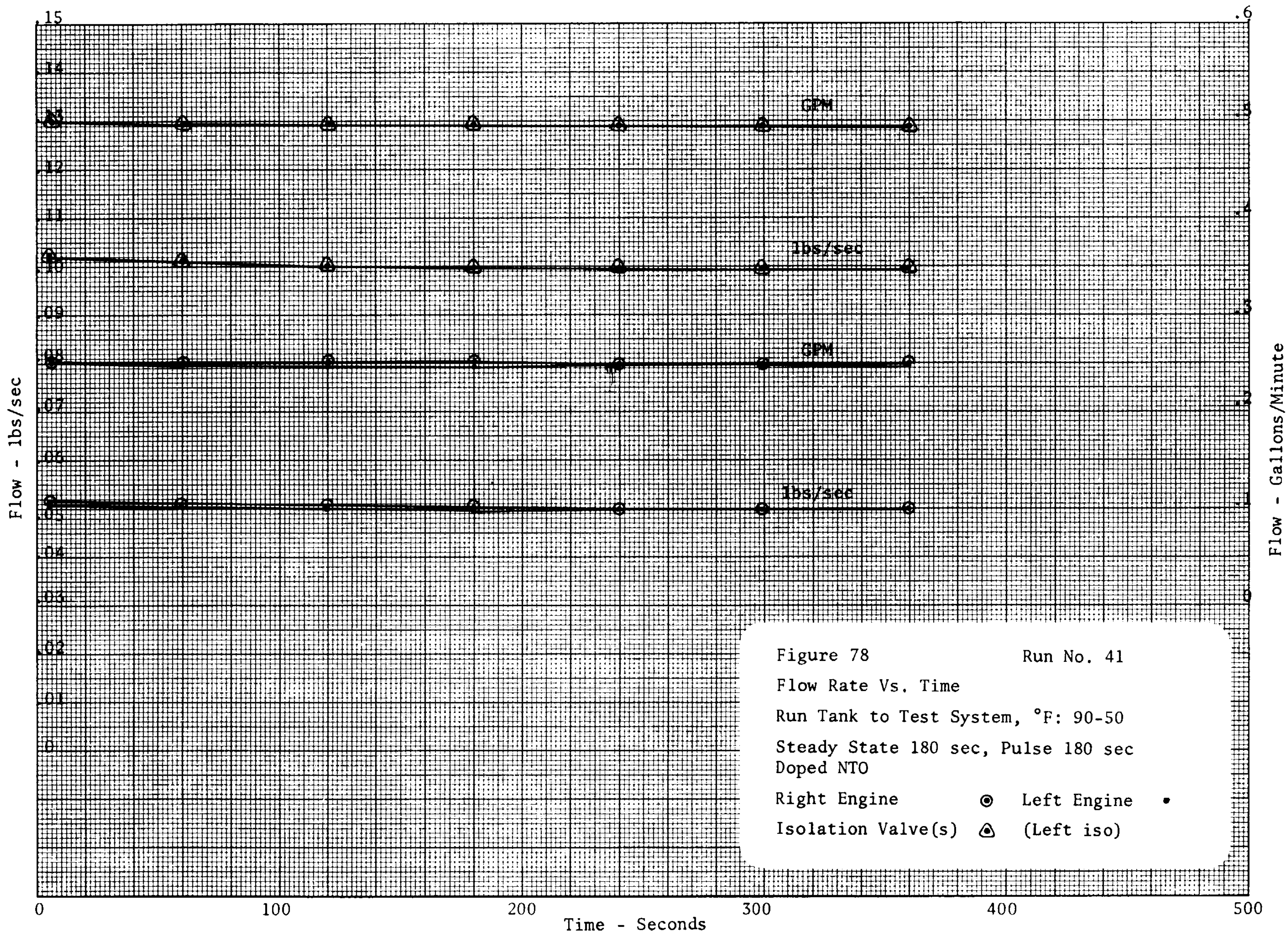


Figure 77 Run No. 41

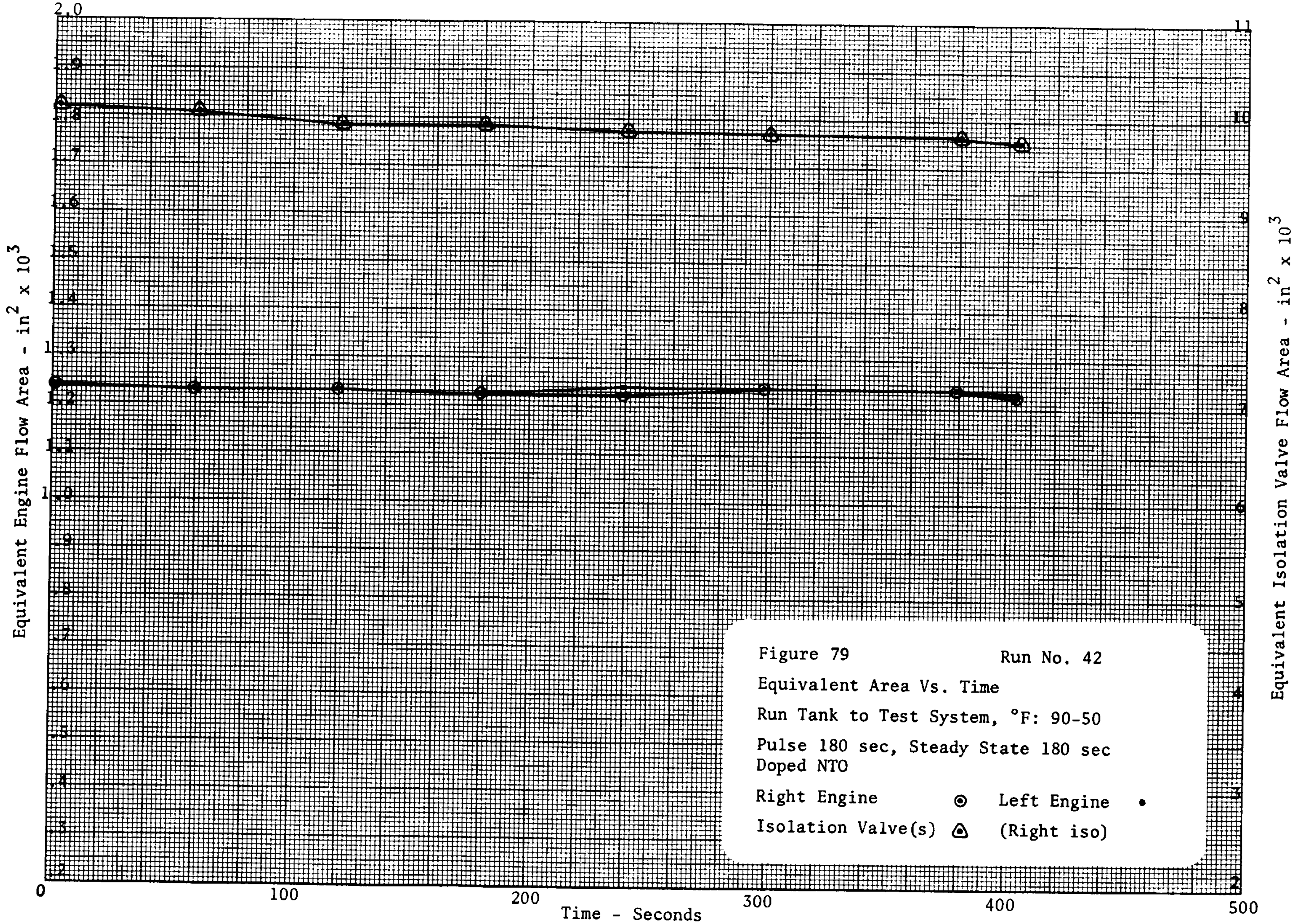
Equivalent Area Vs. Time

Run Tank to Test System, °F: 90-50

Steady State 180 sec, Pulse 180 sec
Doped NTO



.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
Flow - lbs/sec
.6
.5
.4
.3
.2
.1
0
Flow - Gallons/Minute
0
100
200
300
400
500
Time - Seconds
GPM
lbs/sec
GPM
lbs/sec
Figure 78
Run No. 41
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-50
Steady State 180 sec, Pulse 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Left iso)



Equivalent Engine Flow Area - in^2 x 10^3
Equivalent Isolation Valve Flow Area - in^2 x 10^3
Time - Seconds
0
100
200
300
400
500
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
11
10
9
8
7
6
5
4
3
2
Figure 79
Run No. 42
Equivalent Area Vs. Time
Run Tank to Test System, °F: 90-50
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine ⊙ Left Engine •
Isolation Valve(s) △ (Right iso)

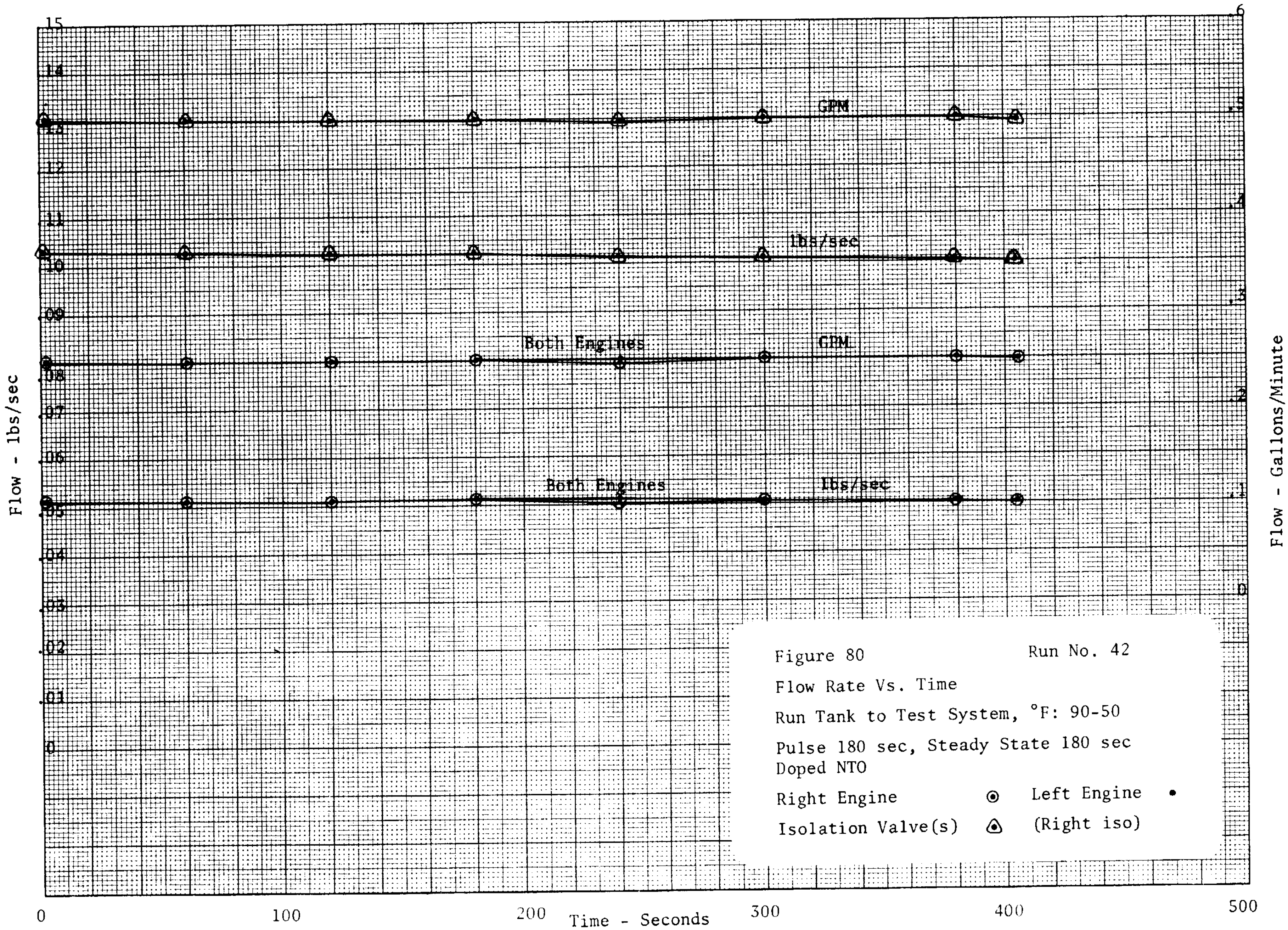


Figure 80
Run No. 42
Flow Rate Vs. Time
Run Tank to Test System, °F: 90-50
Pulse 180 sec, Steady State 180 sec
Doped NTO
Right Engine
Left Engine
Isolation Valve(s)
(Right iso)
GPM
lbs/sec
Both Engines
GPM
Both Engines
lbs/sec
Flow - lbs/sec
Flow - Gallons/Minute
Time - Seconds
0
100
200
300
400
500

APPENDIX V

This Appendix contains a tabular presentation of the data collected during the flow test phase of NAS 8-21489. Included are flow, pressure drop, inlet and outlet temperature, as well as calculated equivalent area in thousandths of a square inch for the isolation valves and engine. Data on the filters was not included as they did not exhibit flow degradation significantly affecting overall system flow over the test program. This tabular data was used in preparing the plots of equivalent area and flow vs. time presented in Appendix IV. While the plots may be used to examine trends, the tabulations should be used in all cases that an actual flow, or equivalent area value is desired.

R U N 2

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
ISOLATION VALVE	3	12.726	.4665	.08627	3.44	150.0	150.0
	10	15.840	.2730	.05049	.76	150.0	150.0
	15	15.185	.2617	.04840	.76	150.0	150.0
	20	16.081	.2772	.05126	.76	150.0	150.0
	30	16.081	.2772	.05126	.76	150.0	150.0
	45	14.735	.2599	.04807	.80	150.0	150.0
	60	14.675	.2647	.04895	.83	150.0	150.0
	120	14.559	.2683	.04961	.87	150.0	150.0
	180	15.644	.2760	.05104	.80	150.0	150.0
	240	16.149	.2849	.05268	.80	150.0	150.0
	300	16.976	.2926	.05411	.76	150.0	150.0
	360	16.942	.2920	.05400	.76	150.0	150.0
	635	14.114	.2956	.05466	1.12	150.0	150.0
	705	13.998	.5050	.09339	3.33	150.0	150.0
	942	13.889	.5091	.09416	3.44	150.0	150.0
	1275	14.640	.5423	.10029	3.51	150.0	150.0
RIGHT ENGINE	3	.836	.1923	.03557	135.43	150.0	150.0
	10	0.000	0.0000	0.00000	137.61	150.0	150.0
	15	0.000	0.0000	0.00000	136.30	150.0	150.0
	20	0.000	0.0000	0.00000	136.09	150.0	150.0
	30	0.000	0.0000	0.00000	135.00	150.0	150.0
	45	0.000	0.0000	0.00000	133.69	150.0	150.0
	60	0.000	0.0000	0.00000	137.83	150.0	150.0
	120	0.000	0.0000	0.00000	139.78	150.0	150.0
	180	0.000	0.0000	0.00000	140.87	150.0	150.0
	240	0.000	0.0000	0.00000	143.04	150.0	150.0
	300	0.000	0.0000	0.00000	141.30	150.0	150.0
	360	0.000	0.0000	0.00000	140.22	150.0	150.0
	635	0.000	0.0000	0.00000	141.30	150.0	150.0
	705	.977	.2243	.04147	135.00	150.0	150.0
	942	.965	.2243	.04147	138.48	150.0	150.0
	1275	1.027	.2420	.04475	142.17	150.0	150.0
LEFT ENGINE	3	1.192	.2742	.05071	135.43	150.0	150.0
	10	1.178	.2730	.05049	137.61	150.0	150.0
	15	1.135	.2617	.04840	136.30	150.0	150.0
	20	1.202	.2772	.05126	136.09	150.0	150.0
	30	1.207	.2772	.05126	135.00	150.0	150.0
	45	1.138	.2599	.04807	133.69	150.0	150.0
	60	1.141	.2647	.04895	137.83	150.0	150.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
R U N 2 C O N T I N U E D							
LEFT ENGINE	120	1.148	.2683	.04961	139.78	150.0	150.0
	180	1.177	.2760	.05104	140.87	150.0	150.0
	240	1.205	.2849	.05268	143.04	150.0	150.0
	300	1.246	.2926	.05411	141.30	150.0	150.0
	360	1.248	.2920	.05400	140.22	150.0	150.0
	635	1.258	.2956	.05466	141.30	150.0	150.0
	705	1.223	.2807	.05191	135.00	150.0	150.0
	942	1.225	.2849	.05268	138.48	150.0	150.0
	1275	1.275	.3003	.05553	142.17	150.0	150.0
R U N 3							
ISOLATION VALVE	5	13.975	.2629	.05252	.98	75.7	75.7
	45	14.279	.2588	.05164	.94	116.5	102.0
	67	15.470	.2801	.05566	.94	126.0	113.8
	225	14.580	.2653	.05097	.91	141.9	137.7
	605	14.230	.2617	.04972	.91	142.7	139.8
	635	14.642	.4836	.09372	3.04	143.8	143.3
	775	15.203	.4913	.09304	2.79	145.8	145.6
	1105	14.906	.4830	.09120	2.79	146.3	145.8
RIGHT ENGINE	5	0.000	0.0000	0.00000	21.74	75.2	75.2
	45	0.000	0.0000	0.00000	21.74	75.2	75.2
	67	0.000	0.0000	0.00000	21.74	75.2	75.2
	225	0.000	0.0000	0.00000	21.74	75.2	75.2
	605	0.000	0.0000	0.00000	21.74	75.2	75.2
	635	1.046	.2243	.04445	129.35	111.5	85.4
	775	1.037	.2278	.04319	128.48	141.9	129.8
	1105	1.030	.2266	.04271	127.61	142.9	134.8
LEFT ENGINE	5	1.180	.2629	.05252	137.17	76.1	76.7
	45	1.175	.2588	.05164	134.35	79.8	77.6
	67	1.271	.2801	.05566	134.78	91.7	82.6
	225	1.207	.2653	.05097	130.43	130.4	117.5
	605	1.185	.2617	.04972	129.56	136.5	127.9
	635	1.186	.2593	.04927	127.17	136.7	127.9
	775	1.210	.2635	.04986	125.65	140.6	131.5
	1105	1.181	.2564	.04848	124.78	141.3	131.9

R U N 4

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
ISOLATION VALVE	40	14.650	.2760	.05507	1.01	113.5	98.5
	75	14.438	.2715	.05382	1.01	129.2	117.7
	120	14.491	.2694	.05377	1.01	137.1	128.3
	180	14.092	.2653	.05124	.98	140.6	135.0
	240	13.856	.2599	.04988	.96	141.7	138.3
	300	14.249	.2605	.04977	.91	143.3	140.0
	360	14.012	.2570	.04894	.91	143.3	141.0
	420	14.105	.2590	.04926	.91	143.5	141.7
	480	13.948	.2564	.04870	.91	143.8	142.1
	540	13.866	.2700	.05124	1.01	143.8	142.7
	600	13.993	.2727	.05171	1.01	143.8	143.8
RIGHT ENGINE	40	0.000	0.0000	0.00000	137.61	75.2	75.2
	75	0.000	0.0000	0.00000	135.76	75.2	75.2
	120	0.000	0.0000	0.00000	136.09	75.2	75.2
	180	0.000	0.0000	0.00000	135.43	75.2	75.2
	240	0.000	0.0000	0.00000	133.69	75.2	75.2
	300	0.000	0.0000	0.00000	133.48	75.2	75.2
	360	0.000	0.0000	0.00000	131.52	75.2	75.2
	420	0.000	0.0000	0.00000	131.74	75.2	75.2
	480	0.000	0.0000	0.00000	130.43	75.2	75.2
	540	0.000	0.0000	0.00000	142.39	75.2	75.2
	600	0.000	0.0000	0.00000	144.78	75.2	75.2
LEFT ENGINE	40	1.237	.2760	.05507	137.61	78.9	77.8
	75	1.228	.2715	.05382	135.76	97.4	85.4
	120	1.236	.2694	.05377	136.09	114.6	77.8
	180	1.188	.2653	.05124	135.43	126.0	112.5
	240	1.167	.2599	.04988	133.69	131.3	118.8
	300	1.167	.2605	.04977	133.48	134.2	122.9
	360	1.157	.2570	.04894	131.52	135.4	125.6
	420	1.165	.2590	.04926	131.74	136.5	127.1
	480	1.158	.2564	.04870	130.43	137.3	127.9
	540	1.166	.2700	.05124	142.39	137.7	129.0
	600	1.172	.2727	.05171	143.48	137.9	129.6

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
R U N 5							
ISOLATION VALVE	15	14.521	.2772	.05807	1.09	53.2	36.0
	19	14.029	.2570	.05384	1.01	69.1	44.1
	30	14.090	.2564	.05371	1.01	84.3	55.5
	55	16.327	.2843	.05924	.94	110.4	87.6
	190	13.964	.2742	.05461	1.12	134.2	123.3
	270	13.695	.2683	.05260	1.09	137.1	130.0
	460	13.372	.2653	.05131	1.09	138.5	134.6
	600	13.323	.2653	.05109	1.09	139.6	135.8
RIGHT ENGINE	15	0.000	0.0000	0.00000	150.00	16.0	16.0
	19	0.000	0.0000	0.00000	135.00	16.0	16.0
	30	0.000	0.0000	0.00000	133.91	16.0	16.0
	55	0.000	0.0000	0.00000	132.39	14.0	14.0
	190	0.000	0.0000	0.00000	136.09	13.5	13.5
	270	0.000	0.0000	0.00000	134.78	13.5	13.5
	460	0.000	0.0000	0.00000	134.78	18.5	19.0
	600	0.000	0.0000	0.00000	136.09	20.9	22.3
LEFT ENGINE	15	1.220	.2772	.05807	150.00	19.8	18.5
	19	1.192	.2570	.05384	135.00	20.2	18.5
	30	1.195	.2564	.05371	133.91	20.9	18.5
	55	1.337	.2843	.05924	132.39	44.1	25.5
	190	1.251	.2742	.05461	136.09	107.6	80.0
	270	1.217	.2683	.05260	134.78	118.3	97.2
	460	1.190	.2653	.05131	134.78	123.3	111.0
	600	1.182	.2653	.05109	136.09	127.5	115.2
R U N 6							
ISOLATION VALVE	8	13.063	.2207	.04633	.83	20.9	16.0
	28	13.996	.2219	.04658	.76	65.7	41.8
	120	13.860	.2254	.04577	.80	130.2	114.6
	360	12.732	.2254	.04367	.87	139.6	135.4
	600	12.501	.2231	.04282	.87	141.7	137.5
RIGHT ENGINE	8	1.042	.2207	.04633	130.43	14.8	16.0
	28	1.047	.2219	.04658	130.87	19.8	16.0
	120	1.056	.2254	.04577	131.74	89.8	57.7
	360	1.026	.2254	.04367	131.74	125.0	109.6
	600	1.010	.2231	.04282	131.52	130.2	118.3

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 6 CONTINUED							
LEFT ENGINE	8	0.000	0.0000	0.00000	130.43	6.2	6.2
	28	0.000	0.0000	0.00000	130.87	16.0	16.0
	120	0.000	0.0000	0.00000	131.74	13.5	13.5
	360	0.000	0.0000	0.00000	131.74	18.5	18.5
	600	0.000	0.0000	0.00000	131.52	23.9	23.9
RUN 7							
ISOLATION VALVE	.1	0.000	0.0000	0.00000	0.00	13.5	11.0
	0	13.877	.5020	.10548	3.80	13.5	11.0
	4	14.669	.4985	.10473	3.37	18.5	18.5
	7	15.505	.4765	.10008	2.79	34.8	31.2
	10	15.787	.4753	.09977	2.72	54.3	44.1
	13	16.051	.4747	.09961	2.64	65.7	52.0
	18	15.907	.4741	.09943	2.72	80.0	62.3
	22	15.716	.4735	.09924	2.83	100.7	76.7
	27	15.625	.4765	.09981	2.90	103.0	90.4
	34	15.736	.4979	.10403	3.15	118.1	96.7
	39	15.721	.5121	.10669	3.33	121.3	101.7
	56	15.345	.4985	.10234	3.26	132.7	120.0
	72	15.193	.4913	.10003	3.19	135.4	123.1
	110	15.212	.4836	.09642	2.97	140.0	132.5
	142	15.126	.4759	.09401	2.86	141.7	135.0
	201	15.052	.4753	.09228	2.79	143.1	139.4
	289	15.093	.4771	.09189	2.75	143.8	140.8
	348	15.177	.4783	.09176	2.72	144.2	141.7
	407	15.246	.4777	.09154	2.68	144.6	142.1
	600	15.291	.4777	.09116	2.64	145.0	143.1
RIGHT ENGINE	.1	0.000	0.0000	0.00000	0.00	11.5	13.5
	0	.943	.2243	.04717	164.56	11.5	13.5
	4	.991	.2243	.04717	149.13	13.5	13.5
	7	1.078	.2243	.04714	126.30	17.3	14.3
	10	1.081	.2243	.04711	125.87	21.8	15.3
	13	1.084	.2243	.04709	125.22	24.1	15.8
	18	1.088	.2243	.04706	124.56	27.7	16.5
	22	1.091	.2243	.04702	124.13	32.4	17.5
	27	1.107	.2266	.04748	123.48	37.1	18.5
	34	1.111	.2266	.04731	122.83	48.6	23.2
	39	1.118	.2278	.04740	122.61	58.2	27.3

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
R U N 7 C O N T I N U E D							
RIGHT ENGINE	56	1.108	.2254	.04616	122.39	94.8	47.3
	72	1.098	.2243	.04550	122.17	103.7	58.4
	110	1.077	.2243	.04451	123.48	120.6	83.9
	142	1.066	.2219	.04362	121.74	125.8	94.6
	201	1.046	.2219	.04290	123.26	131.7	111.5
	289	1.041	.2231	.04282	124.35	134.6	118.3
	348	1.044	.2243	.04289	124.13	136.3	121.9
	407	1.051	.2243	.04283	122.39	136.9	123.1
	600	1.045	.2243	.04269	123.26	138.5	126.0
LEFT ENGINE	-1	0.000	0.0000	0.00000	0.00	14.8	16.0
	0	1.156	.2778	.05831	167.83	14.8	16.0
	4	1.210	.2742	.05756	149.13	15.0	16.0
	7	1.188	.2522	.05294	131.09	17.5	16.3
	10	1.185	.2510	.05266	130.87	20.5	16.8
	13	1.184	.2504	.05252	130.43	21.8	17.3
	18	1.184	.2498	.05237	130.00	24.3	17.8
	22	1.184	.2492	.05222	129.56	27.0	18.5
	27	1.190	.2498	.05232	128.91	30.0	19.0
	34	1.297	.2712	.05672	128.26	37.4	20.9
	39	1.361	.2843	.05929	128.26	45.5	24.3
	56	1.309	.2730	.05618	128.26	82.0	41.1
	72	1.277	.2671	.05453	128.26	93.0	50.7
	110	1.222	.2593	.05191	129.56	114.4	74.3
	142	1.195	.2540	.05039	128.69	120.6	84.3
	201	1.172	.2534	.04937	130.00	131.5	103.7
	289	1.160	.2540	.04907	131.52	134.6	112.3
	348	1.156	.2540	.04888	131.52	136.5	116.0
	407	1.153	.2534	.04871	131.52	136.9	117.1
	600	1.145	.2534	.04847	132.39	138.5	121.7
R U N 8							
ISOLATION VALVE	5	19.072	.5222	.10601	2.11	57.7	57.7
	20	19.005	.5184	.10525	2.09	57.7	57.7
	40	18.953	.5170	.10496	2.09	57.7	57.7
	60	18.975	.5176	.10508	2.09	57.7	57.7
	80	19.019	.5188	.10532	2.09	57.7	57.7
	100	19.008	.5185	.10526	2.09	57.7	57.7

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 8 CONTINUED							
RIGHT ENGINE	5	1.229	.2631	.05342	128.85	57.7	57.7
	20	1.227	.2615	.05308	127.77	57.7	57.7
	40	1.227	.2606	.05291	126.92	57.7	57.7
	60	1.223	.2606	.05291	127.69	57.7	57.7
	80	1.220	.2606	.05291	128.38	57.7	57.7
	100	1.222	.2606	.05291	127.85	57.7	57.7
LEFT ENGINE	5	1.215	.2590	.05259	127.85	57.7	57.7
	20	1.209	.2570	.05217	126.92	57.7	57.7
	40	1.211	.2564	.05205	126.08	57.7	57.7
	60	1.211	.2570	.05217	126.69	57.7	57.7
	80	1.213	.2582	.05241	127.38	57.7	57.7
	100	1.214	.2579	.05235	126.92	57.7	57.7
RUN 9							
ISOLATION VALVE	3	19.752	.5293	.10725	2.02	60.0	61.1
	60	19.561	.5212	.10540	2.00	69.1	68.2
	120	19.567	.5228	.10538	2.00	70.2	70.2
	180	19.507	.5238	.10546	2.02	70.2	70.9
	500	19.008	.5246	.10553	2.12	69.1	76.7
	560	18.956	.5250	.10557	2.14	70.2	71.7
	620	18.958	.5236	.10520	2.12	70.2	71.7
RIGHT ENGINE	3	1.250	.2664	.05398	127.38	60.0	60.0
	60	1.237	.2606	.05271	124.69	65.7	62.3
	120	1.230	.2611	.05262	126.00	69.1	66.1
	180	1.227	.2615	.05265	126.92	70.2	67.5
	500	1.233	.2623	.05276	126.31	71.1	68.6
	560	1.233	.2627	.05282	126.62	71.3	69.1
	620	1.233	.2619	.05262	125.69	71.1	70.0
LEFT ENGINE	3	1.240	.2629	.05327	126.15	60.0	60.0
	60	1.244	.2605	.05269	123.31	65.7	62.3
	120	1.240	.2617	.05276	124.62	69.1	66.1
	180	1.239	.2623	.05282	125.38	70.2	67.5
	500	1.240	.2623	.05276	124.85	71.1	68.6
	560	1.239	.2623	.05274	125.15	71.3	69.1
	620	1.239	.2617	.05258	124.31	71.1	70.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 10							
ISOLATION VALVE	350	17.560	.5135	.10405	2.40	60.0	69.1
	420	17.482	.5135	.10385	2.43	69.1	69.1
	470	17.449	.5135	.10365	2.43	69.1	69.1
RIGHT ENGINE	350	1.203	.2577	.05222	129.23	64.5	60.0
	420	1.205	.2577	.05212	128.69	66.8	62.3
	470	1.203	.2577	.05202	128.85	69.1	64.5
LEFT ENGINE	350	1.198	.2558	.05183	128.08	62.3	60.0
	420	1.201	.2558	.05173	127.54	66.8	62.3
	470	1.199	.2558	.05163	127.69	69.1	64.5
RUN 12							
ISOLATION VALVE	3	18.588	.5125	.10473	2.15	50.9	50.9
	13	18.727	.5117	.10457	2.12	55.5	53.2
	30	18.918	.5120	.10461	2.09	61.1	56.6
	60	19.152	.5161	.10526	2.08	66.8	65.0
	120	19.098	.5161	.10487	2.08	69.1	69.1
	180	18.968	.5155	.10416	2.08	69.1	69.1
RIGHT ENGINE	3	1.237	.2574	.05259	122.54	49.8	49.8
	13	1.236	.2571	.05254	122.54	49.8	49.8
	30	1.238	.2574	.05259	122.38	49.8	49.8
	60	1.247	.2597	.05297	123.31	60.0	52.0
	120	1.250	.2597	.05278	122.46	66.8	56.6
	180	1.241	.2591	.05236	122.54	68.0	63.4
LEFT ENGINE	3	1.229	.2552	.05215	121.92	49.8	49.8
	13	1.227	.2546	.05202	121.85	49.8	49.8
	30	1.228	.2546	.05202	121.69	49.8	49.8
	60	1.234	.2564	.05229	122.54	57.7	52.0
	120	1.238	.2564	.05209	121.62	65.7	56.6
	180	1.232	.2564	.05180	121.62	68.0	63.4
RUN 13							
ISOLATION VALVE	260	18.021	.5060	.10340	2.25	57.7	60.0
	320	18.179	.5114	.10381	2.25	69.1	69.1
	400	18.085	.5081	.10256	2.22	69.1	69.1
	500	17.955	.5054	.10183	2.22	69.1	69.1

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 13 CONTINUED							
RIGHT ENGINE	260	1.226	.2538	.05187	121.46	50.9	49.8
	320	1.237	.2568	.05213	122.12	66.8	57.7
	400	1.228	.2550	.05147	120.92	69.1	64.5
	500	1.219	.2532	.05102	120.69	69.1	66.8
LEFT ENGINE	260	1.223	.2522	.05154	120.38	50.9	49.8
	320	1.233	.2546	.05168	120.85	66.8	57.7
	400	1.225	.2531	.05109	119.77	69.1	64.5
	500	1.220	.2522	.05081	119.46	69.1	66.8
RUN 14							
ISOLATION VALVE	4	17.927	.5114	.10490	2.32	50.9	48.6
	20	17.918	.5075	.10399	2.31	62.7	56.4
	30	17.930	.5051	.10343	2.29	69.1	62.3
	50	18.007	.5081	.10373	2.31	80.0	74.6
	60	17.997	.5084	.10365	2.31	80.4	77.4
	120	17.864	.5093	.10266	2.31	85.4	84.3
	180	17.713	.5084	.10174	2.31	86.5	86.5
	240	17.759	.5102	.10196	2.31	87.4	86.5
	300	17.702	.5078	.10130	2.29	87.4	87.4
RIGHT ENGINE	4	1.232	.2568	.05267	123.38	44.3	45.0
	20	1.234	.2556	.05237	121.77	46.4	46.4
	30	1.231	.2538	.05197	120.85	49.8	47.3
	50	1.242	.2556	.05218	121.00	62.7	50.9
	60	1.254	.2556	.05211	120.54	84.6	52.5
	120	1.238	.2568	.05176	121.62	79.8	66.1
	180	1.226	.2562	.05127	122.08	83.9	74.6
	240	1.223	.2568	.05132	123.00	84.8	76.1
	300	1.219	.2556	.05098	122.38	85.9	78.3
LEFT ENGINE	4	1.227	.2546	.05223	122.54	46.4	45.0
	20	1.221	.2519	.05162	120.85	46.4	46.4
	30	1.222	.2513	.05146	120.00	48.6	47.3
	50	1.229	.2525	.05155	120.04	58.6	50.9
	60	1.234	.2528	.05154	119.62	62.7	52.5
	120	1.221	.2525	.05090	120.77	78.5	66.1
	180	1.212	.2522	.05047	121.08	83.9	74.6
	240	1.212	.2534	.05064	122.00	84.8	76.1
	300	1.207	.2522	.05031	121.46	85.9	78.3

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 15							
ISOLATION VALVE	120	10.059	.4948	.10116	6.86	50.9	53.2
	180	9.932	.4918	.10055	6.95	50.9	55.5
	250	9.981	.4906	.10016	6.92	66.8	64.5
	400	9.646	.4918	.09833	7.14	65.9	87.0
RIGHT ENGINE	120	1.202	.2444	.04996	116.92	48.6	49.1
	180	1.209	.2455	.05020	116.92	49.8	49.1
	250	1.213	.2455	.05013	116.15	53.2	50.9
	400	1.221	.2479	.04957	115.08	84.3	75.7
LEFT ENGINE	120	1.238	.2504	.05120	115.77	48.6	49.1
	180	1.218	.2463	.05035	115.77	49.8	49.1
	250	1.216	.2451	.05003	115.08	53.2	50.9
	400	1.206	.2439	.04876	114.08	84.3	75.7
RUN 16							
ISOLATION VALVE	115	7.018	.5309	.09987	14.89	135.4	147.9
	171	6.811	.5197	.09738	14.77	119.6	139.6
	226	6.803	.5132	.09600	14.15	103.5	129.2
RIGHT ENGINE	115	1.243	.2597	.04891	115.00	143.8	135.4
	171	1.210	.2515	.04724	113.31	143.8	137.5
	226	1.183	.2479	.04646	114.62	143.8	139.6
LEFT ENGINE	115	1.306	.2712	.05095	113.08	143.8	137.5
	171	1.296	.2683	.05014	111.15	143.8	141.7
	226	1.272	.2653	.04955	112.69	143.8	142.3
RUN 17							
ISOLATION VALVE	10	8.015	.5422	.10054	11.78	150.0	150.0
	23	7.974	.5316	.09865	10.46	60.0	83.3
	40	7.553	.4995	.09360	10.40	48.6	66.8
	80	7.650	.4906	.09491	10.31	34.8	45.2
	150	7.830	.4900	.09741	10.31	27.7	36.2
	300	7.828	.4877	.09839	10.49	24.5	31.9
RIGHT ENGINE	10	1.224	.2621	.04873	118.69	150.0	145.8
	23	1.180	.2574	.04794	119.23	118.8	144.4
	40	1.152	.2503	.04713	118.62	99.6	135.4
	80	1.157	.2455	.04763	116.69	69.1	108.3
	150	1.173	.2455	.04891	117.69	48.6	80.0
	300	1.179	.2444	.04942	118.00	39.0	62.3

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 17 CONTINUED							
LEFT ENGINE	10	1.307	.2801	.05180	117.62	150.0	150.0
	23	1.269	.2742	.05071	118.00	139.6	150.0
	40	1.154	.2492	.04646	117.38	121.9	143.8
	80	1.160	.2451	.04728	115.38	77.8	113.5
	150	1.172	.2445	.04851	116.23	52.0	84.3
	300	1.177	.2433	.04897	116.62	42.0	68.0
RUN 18							
ISOLATION VALVE	56	9.648	.4865	.10244	7.42	12.0	12.0
	120	9.546	.4823	.10157	7.45	12.0	12.0
	182	9.491	.4776	.10057	7.38	12.0	12.0
	245	9.562	.4812	.10132	7.38	12.0	12.0
	300	9.627	.4894	.10306	7.54	12.0	12.0
	400	9.507	.4883	.10282	7.69	12.0	12.0
	480	9.454	.4865	.10244	7.72	12.0	12.0
	550	9.450	.4853	.10219	7.69	12.0	12.0
	570	9.461	.4859	.10232	7.69	12.0	12.0
RIGHT ENGINE	56	1.215	.2420	.05096	115.69	12.0	12.0
	120	1.206	.2396	.05046	115.23	12.0	12.0
	182	1.205	.2373	.04996	113.15	12.0	12.0
	245	1.203	.2385	.05021	114.62	12.0	12.0
	300	1.236	.2455	.05171	115.08	12.0	12.0
	400	1.217	.2432	.05121	116.38	12.0	12.0
	480	1.211	.2420	.05096	116.54	12.0	12.0
	550	1.207	.2408	.05071	116.08	12.0	12.0
	570	1.210	.2420	.05096	116.62	12.0	12.0
LEFT ENGINE	56	1.254	.2445	.05148	110.92	12.0	12.0
	120	1.248	.2427	.05111	110.23	12.0	12.0
	182	1.248	.2403	.05061	108.23	12.0	12.0
	245	1.253	.2427	.05111	109.46	12.0	12.0
	300	1.258	.2439	.05136	109.62	12.0	12.0
	400	1.263	.2451	.05161	109.77	12.0	12.0
	480	1.264	.2445	.05148	109.15	12.0	12.0
	550	1.265	.2445	.05148	109.00	12.0	12.0
	570	1.257	.2439	.05136	109.77	12.0	12.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 19							
ISOLATION VALVE	10	9.275	.4829	.10170	7.91	12.0	12.0
	70	9.174	.4823	.10157	8.06	12.0	12.0
	240	9.203	.4829	.10170	8.03	12.0	12.0
	270	9.203	.4829	.10170	8.03	12.0	12.0
	420	9.147	.4800	.10107	8.03	12.0	12.0
	496	9.198	.4817	.10145	8.00	12.0	12.0
	560	9.163	.4817	.10145	8.06	12.0	12.0
	610	9.205	.4811	.10132	7.97	12.0	12.0
RIGHT ENGINE	10	1.303	.2396	.05046	98.69	12.0	12.0
	70	1.309	.2396	.05046	97.69	12.0	12.0
	240	1.310	.2396	.05046	97.54	12.0	12.0
	270	1.299	.2396	.05046	99.31	12.0	12.0
	420	1.280	.2385	.05021	101.15	12.0	12.0
	496	1.268	.2385	.05021	103.08	12.0	12.0
	560	1.265	.2385	.05021	103.62	12.0	12.0
	610	1.271	.2396	.05046	103.62	12.0	12.0
LEFT ENGINE	10	1.226	.2433	.05123	114.85	12.0	12.0
	70	1.227	.2427	.05111	114.15	12.0	12.0
	240	1.232	.2433	.05123	113.77	12.0	12.0
	270	1.232	.2433	.05123	113.77	12.0	12.0
	420	1.223	.2415	.05086	113.69	12.0	12.0
	496	1.232	.2433	.05123	113.77	12.0	12.0
	560	1.232	.2433	.05123	113.69	12.0	12.0
	610	1.225	.2415	.05086	113.31	12.0	12.0
RUN 20							
ISOLATION VALVE	60	9.303	.4984	.09837	7.85	90.0	90.0
	120	9.336	.5002	.09872	7.85	90.0	90.0
	380	9.373	.5031	.09931	7.88	90.0	90.0
	240	9.369	.4960	.09790	7.66	90.0	90.0
	300	9.377	.4984	.09837	7.72	90.0	90.0
	360	9.409	.5031	.09930	7.82	90.0	90.0
RIGHT ENGINE	60	1.146	.2396	.04730	119.54	90.0	90.0
	120	1.155	.2408	.04753	118.92	90.0	90.0
	380	1.166	.2432	.04800	118.92	90.0	90.0
	240	1.170	.2408	.04753	115.77	90.0	90.0
	300	1.169	.2432	.04800	118.31	90.0	90.0
	360	1.181	.2473	.04882	119.92	90.0	90.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
R U N 20 C O N T I N U E D							
LEFT ENGINE	60	1.241	.2588	.05107	118.85	90.0	90.0
	120	1.248	.2593	.05119	118.00	90.0	90.0
	380	1.252	.2599	.05131	117.92	90.0	90.0
	240	1.245	.2552	.05037	114.85	90.0	90.0
	300	1.232	.2552	.05037	117.38	90.0	90.0
	360	1.226	.2558	.05049	119.08	90.0	90.0
R U N 21							
ISOLATION VALVE	3	9.222	.5093	.10053	8.34	90.0	90.0
	60	9.171	.5074	.10015	8.37	90.0	90.0
	120	9.254	.5092	.10050	8.28	90.0	90.0
	180	9.237	.5092	.10050	8.31	90.0	90.0
	240	9.349	.5163	.10191	8.34	90.0	90.0
	300	9.119	.5128	.10122	8.65	90.0	90.0
	360	9.248	.5154	.10174	8.49	90.0	90.0
RIGHT ENGINE	3	1.168	.2494	.04922	124.69	90.0	90.0
	60	1.169	.2481	.04896	123.00	90.0	90.0
	120	1.164	.2481	.04896	124.15	90.0	90.0
	180	1.164	.2481	.04896	124.15	90.0	90.0
	240	1.195	.2546	.05025	124.08	90.0	90.0
	300	1.179	.2511	.04956	123.92	90.0	90.0
	360	1.190	.2537	.05008	124.23	90.0	90.0
LEFT ENGINE	3	1.224	.2599	.05131	123.31	90.0	90.0
	60	1.231	.2593	.05119	121.38	90.0	90.0
	120	1.232	.2611	.05154	122.77	90.0	90.0
	180	1.232	.2611	.05154	122.77	90.0	90.0
	240	1.235	.2617	.05166	122.69	90.0	90.0
	300	1.235	.2617	.05166	122.69	90.0	90.0
	360	1.235	.2617	.05166	122.85	90.0	90.0
R U N 22							
ISOLATION VALVE	2	9.799	.5075	.10214	7.48	68.0	68.0
	60	9.872	.5028	.10119	7.23	68.0	68.0
	120	9.819	.5012	.10087	7.26	68.0	68.0
	180	9.769	.5018	.10099	7.35	68.0	68.0
	240	9.682	.5004	.10071	7.45	68.0	68.0
	300	9.840	.5012	.10087	7.23	68.0	68.0

	TIME	AREA SQ.IN	FLØW GPM	FLØW PPS	PRESSURE PSI	INLET DEG F	ØUTLET DEG F
R U N 22 C Ø N T I N U E D							
ISØLATIØN VALVE	360	9.829	.5006	.10075	7.23	68.0	68.0
RIGHT ENGINE	2	1.215	.2494	.05019	117.38	68.0	68.0
	60	1.209	.2476	.04983	117.00	68.0	68.0
	120	1.205	.2472	.04975	117.23	68.0	68.0
	180	1.202	.2472	.04975	117.85	68.0	68.0
	240	1.207	.2476	.04983	117.31	68.0	68.0
	300	1.203	.2472	.04975	117.77	68.0	68.0
	360	1.205	.2472	.04975	117.31	68.0	68.0
LEFT ENGINE	2	1.246	.2582	.05196	119.62	68.0	68.0
	60	1.238	.2552	.05136	118.46	68.0	68.0
	120	1.232	.2540	.05112	118.46	68.0	68.0
	180	1.233	.2546	.05124	118.92	68.0	68.0
	240	1.223	.2528	.05088	119.15	68.0	68.0
	300	1.230	.2540	.05112	118.85	68.0	68.0
	360	1.230	.2534	.05100	118.23	68.0	68.0
R U N 23							
ISØLATIØN VALVE	5	9.392	.5118	.10300	8.28	68.0	68.0
	60	9.465	.5090	.10244	8.06	68.0	68.0
	120	9.472	.5084	.10232	8.03	68.0	68.0
	180	9.479	.5078	.10220	8.00	68.0	68.0
	240	9.468	.5072	.10208	8.00	68.0	68.0
	300	9.407	.5078	.10220	8.12	68.0	68.0
	360	9.389	.5078	.10220	8.15	68.0	68.0
RIGHT ENGINE	5	1.206	.2524	.05080	122.08	68.0	68.0
	60	1.198	.2502	.05036	121.62	68.0	68.0
	120	1.200	.2502	.05036	121.15	68.0	68.0
	180	1.202	.2502	.05036	120.77	68.0	68.0
	240	1.199	.2502	.05036	121.46	68.0	68.0
	300	1.193	.2502	.05036	122.69	68.0	68.0
	360	1.193	.2502	.05036	122.69	68.0	68.0
LEFT ENGINE	5	1.232	.2593	.05220	123.62	68.0	68.0
	60	1.231	.2588	.05208	123.08	68.0	68.0
	120	1.232	.2582	.05196	122.46	68.0	68.0
	180	1.231	.2576	.05184	122.08	68.0	68.0
	240	1.227	.2570	.05172	122.31	68.0	68.0
	300	1.224	.2576	.05184	123.46	68.0	68.0
	360	1.224	.2576	.05184	123.46	68.0	68.0

RUN 24

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
ISOLATION VALVE	1	10.049	.5025	.10267	7.08	50.0	50.0
	2	9.896	.4960	.10133	7.11	50.0	50.0
	60	9.904	.4931	.10075	7.02	50.0	50.0
	61	9.872	.4915	.10042	7.02	50.0	50.0
	62	9.803	.4881	.09973	7.02	50.0	50.0
	120	9.788	.4852	.09913	6.95	50.0	50.0
	180	9.803	.4881	.09973	7.02	50.0	50.0
	240	9.890	.4903	.10017	6.95	50.0	50.0
	300	9.890	.4903	.10017	6.95	50.0	50.0
	360	9.833	.4917	.10046	7.08	50.0	50.0
RIGHT ENGINE	1	1.221	.2432	.04968	112.31	50.0	50.0
	2	1.216	.2432	.04968	113.08	50.0	50.0
	60	1.209	.2397	.04898	111.23	50.0	50.0
	61	1.208	.2393	.04889	111.00	50.0	50.0
	62	1.207	.2389	.04881	110.77	50.0	50.0
	120	1.201	.2372	.04846	110.38	50.0	50.0
	180	1.208	.2389	.04881	110.69	50.0	50.0
	240	1.226	.2410	.04924	109.46	50.0	50.0
	300	1.232	.2410	.04924	108.38	50.0	50.0
	360	1.236	.2419	.04942	108.46	50.0	50.0
LEFT ENGINE	1	1.264	.2593	.05299	119.08	50.0	50.0
	2	1.237	.2528	.05165	118.23	50.0	50.0
	60	1.249	.2534	.05177	116.54	50.0	50.0
	61	1.245	.2522	.05153	116.15	50.0	50.0
	62	1.231	.2492	.05092	116.08	50.0	50.0
	120	1.228	.2481	.05068	115.54	50.0	50.0
	180	1.229	.2492	.05092	116.46	50.0	50.0
	240	1.230	.2492	.05092	116.23	50.0	50.0
	300	1.230	.2492	.05092	116.15	50.0	50.0
	360	1.230	.2498	.05104	116.69	50.0	50.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 25							
ISOLATION VALVE	1	9.716	.5096	.10411	7.78	50.0	50.0
	60	9.678	.5096	.10411	7.85	50.0	50.0
	120	9.660	.5077	.10372	7.82	50.0	50.0
	180	9.630	.5071	.10360	7.85	50.0	50.0
	240	9.502	.5081	.10381	8.09	50.0	50.0
	300	9.510	.5105	.10429	8.15	50.0	50.0
	360	9.511	.5096	.10411	8.12	50.0	50.0
RIGHT ENGINE	1	1.251	.2526	.05161	115.38	50.0	50.0
	60	1.248	.2526	.05161	115.92	50.0	50.0
	120	1.243	.2513	.05135	115.77	50.0	50.0
	180	1.244	.2513	.05135	115.46	50.0	50.0
	240	1.239	.2518	.05144	116.77	50.0	50.0
	300	1.241	.2535	.05179	118.08	50.0	50.0
	360	1.237	.2526	.05161	118.08	50.0	50.0
LEFT ENGINE	1	1.243	.2570	.05250	121.00	50.0	50.0
	60	1.242	.2570	.05250	121.15	50.0	50.0
	120	1.241	.2564	.05238	120.85	50.0	50.0
	180	1.239	.2558	.05226	120.62	50.0	50.0
	240	1.239	.2564	.05238	121.15	50.0	50.0
	300	1.236	.2570	.05250	122.31	50.0	50.0
	360	1.236	.2570	.05250	122.31	50.0	50.0
RUN 26							
ISOLATION VALVE	1	9.939	.4984	.10348	7.23	30.0	30.0
	4	9.833	.4930	.10237	7.23	30.0	30.0
	15	9.936	.4886	.10144	6.95	30.0	30.0
	60	9.870	.4800	.09965	6.80	30.0	30.0
	120	9.873	.4833	.10035	6.89	30.0	30.0
	200	9.908	.4861	.10093	6.92	30.0	30.0
	260	9.939	.4930	.10237	7.08	30.0	30.0
	300	9.912	.4917	.10210	7.08	30.0	30.0
RIGHT ENGINE	1	1.205	.2450	.05087	118.85	30.0	30.0
	4	1.206	.2450	.05087	118.69	30.0	30.0
	15	1.215	.2441	.05069	116.08	30.0	30.0
	60	1.209	.2385	.04951	111.92	30.0	30.0
	120	1.215	.2406	.04996	112.77	30.0	30.0
	200	1.201	.2411	.05005	115.92	30.0	30.0
	260	1.211	.2450	.05087	117.77	30.0	30.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
R U N 26 C O N T I N U E D							
RIGHT ENGINE	300	1.206	.2437	.05059	117.38	30.0	30.0
LEFT ENGINE	1	1.246	.2534	.05261	118.85	30.0	30.0
	4	1.221	.2481	.05150	118.69	30.0	30.0
	15	1.217	.2445	.05076	116.08	30.0	30.0
	60	1.224	.2415	.05014	111.92	30.0	30.0
	120	1.226	.2427	.05039	112.77	30.0	30.0
	200	1.221	.2451	.05088	115.92	30.0	30.0
	260	1.226	.2481	.05150	117.77	30.0	30.0
	300	1.228	.2481	.05150	117.38	30.0	30.0
R U N 27							
ISOLATION VALVE	1	9.575	.5021	.10425	7.91	30.0	30.0
	60	9.540	.5013	.10407	7.94	30.0	30.0
	120	9.493	.4959	.10295	7.85	30.0	30.0
	180	9.432	.4975	.10329	8.00	30.0	30.0
	240	9.516	.4980	.10340	7.88	30.0	30.0
	300	9.535	.4980	.10340	7.85	30.0	30.0
	360	9.496	.4970	.10319	7.88	30.0	30.0
RIGHT ENGINE	1	1.222	.2511	.05213	121.46	30.0	30.0
	60	1.222	.2502	.05195	120.62	30.0	30.0
	120	1.198	.2454	.05096	120.69	30.0	30.0
	180	1.193	.2459	.05105	122.23	30.0	30.0
	240	1.168	.2476	.05141	129.23	30.0	30.0
	300	1.205	.2476	.05141	121.38	30.0	30.0
	360	1.206	.2472	.05132	120.77	30.0	30.0
LEFT ENGINE	1	1.221	.2510	.05212	121.46	30.0	30.0
	60	1.226	.2510	.05212	120.62	30.0	30.0
	120	1.222	.2504	.05199	120.69	30.0	30.0
	180	1.220	.2516	.05224	122.23	30.0	30.0
	240	1.218	.2504	.05199	121.54	30.0	30.0
	300	1.219	.2504	.05199	121.38	30.0	30.0
	360	1.219	.2498	.05187	120.77	30.0	30.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
R U N 28							
ISOLATION VALVE	2	17.731	.5023	.10429	2.31	30.0	30.0
	25	17.840	.4986	.10352	2.25	30.0	30.0
	29	16.509	.2533	.05259	.68	30.0	30.0
	54	16.509	.2533	.05259	.68	30.0	30.0
	57	16.632	.2552	.05298	.68	30.0	30.0
	81	16.516	.2534	.05261	.68	30.0	30.0
RIGHT ENGINE	2	1.228	.2507	.05204	119.77	30.0	30.0
	25	1.228	.2494	.05177	118.54	30.0	30.0
	29	1.225	.2533	.05259	122.85	30.0	30.0
	54	1.224	.2533	.05259	123.23	30.0	30.0
	57	0.000	0.0000	0.00000	121.54	30.0	30.0
	81	0.000	0.0000	0.00000	121.62	30.0	30.0
LEFT ENGINE	2	1.233	.2516	.05224	119.77	30.0	30.0
	25	1.228	.2492	.05175	118.54	30.0	30.0
	29	0.000	0.0000	0.00000	122.85	30.0	30.0
	54	0.000	0.0000	0.00000	123.23	30.0	30.0
	57	1.241	.2552	.05298	121.54	30.0	30.0
	81	1.232	.2534	.05261	121.62	30.0	30.0
R U N 29							
ISOLATION VALVE	3	9.138	.5041	.10156	8.49	66.8	66.6
	60	9.317	.5095	.10258	8.34	67.3	67.3
	120	9.294	.5067	.10200	8.31	70.4	67.7
	183	9.328	.5133	.10328	8.46	71.5	68.9
	186	9.538	.5249	.10560	8.46	71.5	68.9
	189	9.383	.5154	.10370	8.43	71.5	68.9
	240	9.406	.5142	.10293	8.37	85.7	82.2
	300	9.187	.5069	.10101	8.46	87.2	85.7
	360	9.181	.5074	.10093	8.46	87.6	86.1
RIGHT ENGINE	3	1.215	.2489	.05015	117.15	66.6	66.8
	60	1.214	.2472	.04977	115.54	67.3	67.5
	120	1.172	.2385	.04800	115.38	67.7	67.7
	183	1.215	.2481	.04991	116.15	68.9	68.4
	186	1.229	.2507	.05043	116.00	68.9	68.4
	189	1.214	.2472	.04973	115.54	68.9	68.4
	240	1.229	.2472	.04948	113.00	82.2	74.3
	300	1.214	.2446	.04874	112.69	85.7	79.3
	360	1.213	.2463	.04899	114.08	86.1	81.5

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 29 CONTINUED							
LEFT ENGINE	3	1.244	.2552	.05141	117.46	67.7	66.8
	60	1.289	.2623	.05282	115.54	67.5	67.5
	120	1.319	.2683	.05400	115.38	67.7	67.7
	183	1.299	.2653	.05337	116.15	68.4	68.4
	186	1.344	.2742	.05516	116.00	68.4	68.4
	189	1.317	.2683	.05397	115.54	68.4	68.4
	240	1.326	.2671	.05346	113.00	80.4	74.3
	300	1.301	.2623	.05228	112.69	84.3	79.3
	360	1.285	.2611	.05194	114.08	85.4	81.5
RUN 30							
ISOLATION VALVE	3	9.660	.4886	.09844	7.14	66.8	66.8
	20	9.606	.4816	.09700	7.05	72.8	68.6
	33	9.968	.4996	.10060	7.08	79.1	70.9
	36	10.151	.5085	.10237	7.08	80.7	71.3
	55	10.157	.5090	.10228	7.08	83.9	75.7
	120	10.003	.5048	.10083	7.11	86.5	83.7
	180	10.024	.5060	.10078	7.08	87.6	85.0
	240	10.069	.5142	.10242	7.23	85.7	84.3
	300	10.046	.5133	.10224	7.23	84.3	83.5
	360	10.194	.5177	.10312	7.14	83.5	82.8
RIGHT ENGINE	3	1.216	.2441	.04918	112.46	66.8	66.8
	20	1.198	.2389	.04812	111.15	68.6	67.0
	33	1.223	.2433	.04898	110.62	70.9	67.5
	36	1.218	.2433	.04897	111.54	71.3	67.7
	55	1.222	.2437	.04897	111.23	75.7	69.8
	120	1.217	.2437	.04868	111.54	83.7	76.7
	180	1.216	.2437	.04854	111.31	85.0	80.0
	240	1.226	.2489	.04958	114.08	84.3	80.0
	300	1.223	.2481	.04941	113.92	83.5	80.0
	360	1.233	.2507	.04993	114.23	82.8	80.0
LEFT ENGINE	3	1.218	.2445	.04925	112.46	66.8	66.8
	20	1.216	.2427	.04889	111.15	68.0	67.0
	33	1.288	.2564	.05162	110.62	69.5	67.5
	36	1.328	.2653	.05340	111.54	70.0	67.7
	55	1.329	.2653	.05331	111.23	73.5	69.8
	120	1.304	.2611	.05216	111.54	82.6	76.7
	180	1.308	.2623	.05225	111.31	84.3	80.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 30 CONTINUED							
LEFT ENGINE	240	1.306	.2653	.05284	114.08	83.3	80.0
	300	1.307	.2653	.05284	113.92	82.6	80.0
	360	1.313	.2671	.05319	114.23	81.7	80.0
RUN 31							
ISOLATION VALVE	3	9.703	.5054	.10327	7.69	52.0	49.8
	60	9.762	.5062	.10343	7.63	53.2	49.8
	120	9.667	.4993	.10203	7.60	57.7	49.8
	180	9.823	.5055	.10329	7.57	61.8	49.8
	250	9.332	.4919	.09985	8.00	85.4	73.5
	300	9.107	.4872	.09796	8.09	86.5	82.0
	350	8.963	.4807	.09620	8.06	87.0	84.3
	360	9.036	.4846	.09699	8.06	87.0	84.3
RIGHT ENGINE	3	1.253	.2454	.05015	108.54	49.8	49.8
	60	1.244	.2433	.04971	108.23	49.8	49.8
	120	1.226	.2376	.04855	106.31	49.8	49.8
	180	1.250	.2402	.04908	104.46	49.8	49.8
	250	1.242	.2385	.04841	105.08	73.5	57.7
	300	1.242	.2415	.04856	106.46	82.0	69.1
	350	1.224	.2380	.04763	105.69	84.3	74.6
	360	1.244	.2419	.04842	105.69	84.3	74.6
LEFT ENGINE	3	1.321	.2599	.05312	109.54	49.8	49.8
	60	1.321	.2629	.05372	112.15	49.8	49.8
	120	1.326	.2617	.05348	110.31	49.8	49.8
	180	1.355	.2653	.05421	108.54	49.8	49.8
	250	1.289	.2534	.05144	109.46	65.7	57.7
	300	1.236	.2457	.04940	111.00	80.0	69.1
	350	1.222	.2427	.04857	110.00	82.4	74.6
	360	1.222	.2427	.04857	110.08	82.4	74.6
RUN 32							
ISOLATION VALVE	3	10.289	.4833	.09895	6.28	51.4	47.5
	17	10.272	.4812	.09848	6.28	58.9	47.5
	19	10.191	.4768	.09757	6.28	62.0	48.6
	23	10.367	.4841	.09904	6.28	67.3	52.0
	33	10.499	.4942	.10104	6.46	83.7	55.2
	50	10.586	.5013	.10223	6.49	81.1	64.5

RUN 32 CONTINUED

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
ISOLATION VALVE	110	10.380	.4995	.10069	6.58	87.0	80.0
	180	10.237	.4968	.09954	6.62	87.0	82.8
	240	10.322	.5021	.10058	6.62	82.2	80.0
	300	10.337	.5028	.10073	6.62	82.2	80.0
	360	10.250	.4997	.10011	6.65	82.2	80.0
	362	10.405	.5061	.10138	6.62	82.2	80.0
RIGHT ENGINE	3	1.248	.2406	.04926	105.38	47.5	47.5
	17	1.241	.2385	.04881	104.62	47.5	47.7
	19	1.219	.2341	.04790	104.54	48.6	48.0
	23	1.245	.2385	.04878	104.31	52.0	48.4
	33	1.257	.2402	.04911	103.85	55.2	49.1
	50	1.260	.2402	.04898	103.77	64.5	52.3
	110	1.256	.2419	.04877	104.77	80.0	66.1
	180	1.252	.2428	.04865	105.23	82.8	73.3
	240	1.249	.2446	.04899	107.00	80.0	73.5
	300	1.254	.2459	.04925	107.31	80.0	73.5
	360	1.245	.2446	.04899	107.69	80.0	73.5
	362	1.248	.2450	.04908	107.54	80.0	73.5
LEFT ENGINE	3	1.227	.2427	.04969	111.00	47.5	47.5
	17	1.232	.2427	.04968	110.08	47.5	47.7
	19	1.232	.2427	.04967	110.00	48.0	48.0
	23	1.250	.2457	.05026	109.69	50.2	48.4
	33	1.295	.2540	.05193	109.23	52.3	49.1
	50	1.334	.2611	.05325	108.85	60.0	52.3
	110	1.307	.2576	.05192	109.77	80.0	66.1
	180	1.280	.2540	.05089	110.00	80.4	73.3
	240	1.288	.2576	.05159	111.38	77.8	73.5
	300	1.285	.2570	.05147	111.31	77.8	73.5
	360	1.276	.2552	.05112	111.31	77.8	73.5
	362	1.307	.2611	.05231	111.23	77.8	73.5
RUN 33							
ISOLATION VALVE	3	8.879	.5002	.09874	8.68	90.0	90.0
	10	8.882	.4968	.09807	8.55	90.0	90.0
	60	8.915	.4868	.09610	8.15	90.0	90.0
	120	8.872	.4936	.09743	8.46	90.0	90.0
	180	8.898	.4977	.09824	8.55	90.0	90.0
	240	8.876	.5027	.09923	8.77	90.0	90.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 33 CONTINUED							
ISOLATION VALVE	300	8.930	.5049	.09965	8.74	90.0	90.0
	360	8.856	.5033	.09935	8.83	90.0	90.0
RIGHT ENGINE	3	1.216	.2498	.04931	115.31	90.0	90.0
	10	1.219	.2485	.04905	113.69	90.0	90.0
	60	1.214	.2433	.04801	109.85	90.0	90.0
	120	1.214	.2467	.04870	112.85	90.0	90.0
	180	1.214	.2485	.04905	114.54	90.0	90.0
	240	1.215	.2511	.04956	116.69	90.0	90.0
	300	1.213	.2518	.04969	117.77	90.0	90.0
	360	1.214	.2511	.04956	116.92	90.0	90.0
LEFT ENGINE	3	1.221	.2504	.04943	114.92	90.0	90.0
	10	1.220	.2483	.04902	113.31	90.0	90.0
	60	1.217	.2436	.04808	109.46	90.0	90.0
	120	1.218	.2469	.04873	112.31	90.0	90.0
	180	1.221	.2492	.04920	114.00	90.0	90.0
	240	1.221	.2516	.04967	116.15	90.0	90.0
	300	1.222	.2531	.04996	117.31	90.0	90.0
	360	1.217	.2522	.04978	117.46	90.0	90.0
RUN 34							
ISOLATION VALVE	3	9.603	.5068	.10004	7.62	90.0	90.0
	60	9.477	.5042	.09952	7.74	90.0	90.0
	120	9.447	.5021	.09911	7.72	90.0	90.0
	180	9.492	.5004	.09878	7.60	90.0	90.0
	240	9.544	.5063	.09993	7.69	90.0	90.0
	300	9.522	.5051	.09969	7.69	90.0	90.0
	360	9.550	.5056	.09979	7.66	90.0	90.0
RIGHT ENGINE	3	1.220	.2537	.05008	118.15	90.0	90.0
	60	1.214	.2520	.04974	117.69	90.0	90.0
	120	1.215	.2511	.04956	116.85	90.0	90.0
	180	1.210	.2500	.04935	116.77	90.0	90.0
	240	1.209	.2529	.04991	119.62	90.0	90.0
	300	1.215	.2529	.04991	118.46	90.0	90.0
	360	1.217	.2531	.04995	118.31	90.0	90.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 34 CONTINUED							
LEFT ENGINE	3	1.220	.2531	.04996	117.69	90.0	90.0
	60	1.219	.2522	.04978	117.00	90.0	90.0
	120	1.217	.2510	.04955	116.31	90.0	90.0
	180	1.215	.2504	.04943	116.15	90.0	90.0
	240	1.217	.2534	.05002	118.62	90.0	90.0
	300	1.214	.2522	.04978	117.92	90.0	90.0
	360	1.217	.2525	.04984	117.69	90.0	90.0
RUN 35							
ISOLATION VALVE	3	9.143	.4945	.09934	8.14	70.0	70.0
	60	9.085	.4843	.09731	7.91	70.0	70.0
	120	9.135	.4884	.09812	7.95	70.0	70.0
	180	9.112	.4886	.09816	8.00	70.0	70.0
	240	9.078	.4914	.09873	8.15	70.0	70.0
	300	9.095	.4918	.09882	8.14	70.0	70.0
	360	9.137	.4923	.09891	8.08	70.0	70.0
RIGHT ENGINE	3	1.229	.2485	.04993	113.85	70.0	70.0
	60	1.221	.2428	.04879	110.00	70.0	70.0
	120	1.221	.2448	.04918	111.92	70.0	70.0
	180	1.222	.2450	.04922	111.92	70.0	70.0
	240	1.212	.2454	.04931	114.15	70.0	70.0
	300	1.215	.2459	.04940	114.00	70.0	70.0
	360	1.216	.2463	.04949	114.23	70.0	70.0
LEFT ENGINE	3	1.216	.2460	.04942	113.85	70.0	70.0
	60	1.215	.2415	.04852	110.00	70.0	70.0
	120	1.215	.2436	.04894	111.92	70.0	70.0
	180	1.215	.2436	.04894	111.92	70.0	70.0
	240	1.214	.2460	.04942	114.15	70.0	70.0
	300	1.215	.2460	.04942	114.00	70.0	70.0
	360	1.214	.2460	.04942	114.23	70.0	70.0
RUN 36							
ISOLATION VALVE	3	9.714	.4952	.09949	7.23	70.0	70.0
	60	9.597	.4918	.09881	7.31	70.0	70.0
	120	9.562	.4905	.09855	7.32	70.0	70.0
	180	9.600	.4920	.09885	7.31	70.0	70.0
	240	9.647	.4944	.09933	7.31	70.0	70.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 36 CONTINUED							
ISOLATION VALVE	300	9.631	.4946	.09937	7.34	70.0	70.0
	360	9.613	.4942	.09928	7.35	70.0	70.0
RIGHT ENGINE	3	1.225	.2489	.05001	114.85	70.0	70.0
	60	1.216	.2467	.04957	114.62	70.0	70.0
	120	1.210	.2454	.04931	114.54	70.0	70.0
	180	1.214	.2463	.04949	114.62	70.0	70.0
	240	1.223	.2487	.04997	115.08	70.0	70.0
	300	1.227	.2489	.05001	114.62	70.0	70.0
	360	1.225	.2485	.04993	114.54	70.0	70.0
LEFT ENGINE	3	1.212	.2463	.04948	114.85	70.0	70.0
	60	1.208	.2451	.04924	114.62	70.0	70.0
	120	1.208	.2451	.04924	114.54	70.0	70.0
	180	1.213	.2457	.04936	114.23	70.0	70.0
	240	1.210	.2457	.04936	114.69	70.0	70.0
	300	1.212	.2457	.04936	114.31	70.0	70.0
	360	1.213	.2457	.04936	114.08	70.0	70.0
RUN 37							
ISOLATION VALVE	3	9.535	.4946	.10106	7.62	50.0	50.0
	60	9.454	.4850	.09908	7.45	50.0	50.0
	70	9.808	.5026	.10268	7.43	50.0	50.0
	120	9.928	.5088	.10394	7.43	50.0	50.0
	180	10.083	.5183	.10589	7.48	50.0	50.0
	240	9.939	.5109	.10437	7.48	50.0	50.0
	300	9.859	.5073	.10365	7.49	50.0	50.0
	360	9.963	.5106	.10431	7.43	50.0	50.0
RIGHT ENGINE	3	1.247	.2472	.05050	111.15	50.0	50.0
	60	1.249	.2435	.04974	107.54	50.0	50.0
	70	1.249	.2433	.04970	107.31	50.0	50.0
	120	1.248	.2435	.04974	107.62	50.0	50.0
	180	1.246	.2441	.04988	108.62	50.0	50.0
	240	1.248	.2450	.05005	109.00	50.0	50.0
	300	1.249	.2450	.05005	108.85	50.0	50.0
	360	1.253	.2459	.05023	109.00	50.0	50.0

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 37 CONTINUED							
LEFT ENGINE	3	1.227	.2475	.05056	115.00	50.0	50.0
	60	1.217	.2415	.04934	111.38	50.0	50.0
	70	1.286	.2593	.05299	115.00	50.0	50.0
	120	1.334	.2653	.05420	111.92	50.0	50.0
	180	1.371	.2742	.05602	113.23	50.0	50.0
	240	1.328	.2659	.05432	113.46	50.0	50.0
	300	1.311	.2623	.05359	113.23	50.0	50.0
	360	1.322	.2647	.05408	113.38	50.0	50.0
RUN 38							
ISOLATION VALVE	3	10.138	.5206	.10636	7.46	50.0	50.0
	60	10.044	.5163	.10548	7.48	50.0	50.0
	120	9.930	.5099	.10418	7.46	50.0	50.0
	180	10.040	.5156	.10533	7.46	50.0	50.0
	240	10.103	.5182	.10588	7.45	50.0	50.0
	300	10.082	.5182	.10588	7.48	50.0	50.0
	360	10.131	.5197	.10618	7.45	50.0	50.0
RIGHT ENGINE	3	1.257	.2494	.05095	111.38	50.0	50.0
	60	1.247	.2481	.05068	111.92	50.0	50.0
	120	1.244	.2476	.05059	112.08	50.0	50.0
	180	1.247	.2485	.05077	112.31	50.0	50.0
	240	1.243	.2476	.05059	112.23	50.0	50.0
	300	1.242	.2476	.05059	112.46	50.0	50.0
	360	1.245	.2485	.05077	112.69	50.0	50.0
LEFT ENGINE	3	1.349	.2712	.05541	114.46	50.0	50.0
	60	1.333	.2683	.05481	114.62	50.0	50.0
	120	1.304	.2623	.05359	114.46	50.0	50.0
	180	1.331	.2671	.05456	113.85	50.0	50.0
	240	1.348	.2706	.05529	114.08	50.0	50.0
	300	1.348	.2706	.05529	114.08	50.0	50.0
	360	1.352	.2712	.05541	113.92	50.0	50.0
RUN 39							
ISOLATION VALVE	3	9.213	.5006	.10075	8.23	68.0	68.0
	60	9.149	.4939	.09912	8.20	85.2	85.2
	120	9.163	.4980	.09936	8.23	87.4	87.4
	180	9.155	.4951	.09857	8.12	88.5	88.7

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 39 CONTINUED							
ISOLATION VALVE	240	9.068	.4963	.09882	8.31	86.5	92.6
	300	9.086	.4998	.09953	8.38	85.4	93.3
	360	9.031	.4992	.09943	8.46	84.3	93.5
RIGHT ENGINE	3	1.219	.2496	.05023	116.77	68.0	68.0
	60	1.232	.2476	.04969	112.92	77.2	71.3
	120	1.230	.2494	.04975	114.23	84.8	78.0
	180	1.228	.2476	.04930	112.77	86.3	80.4
	240	1.225	.2476	.04931	113.23	85.4	80.2
	300	1.224	.2494	.04966	114.85	83.9	80.2
	360	1.225	.2494	.04967	114.62	83.7	80.0
LEFT ENGINE	3	1.226	.2510	.05052	116.77	68.0	68.0
	60	1.224	.2463	.04942	112.92	75.0	71.3
	120	1.226	.2486	.04961	114.23	83.3	78.0
	180	1.226	.2475	.04927	112.77	85.2	80.4
	240	1.229	.2486	.04951	113.23	84.1	80.2
	300	1.229	.2504	.04987	114.85	84.1	80.2
	360	1.227	.2498	.04976	114.62	82.2	80.0
RUN 40							
ISOLATION VALVE	3	9.702	.4994	.10045	7.38	69.1	69.1
	60	9.650	.4952	.09961	7.34	69.1	75.0
	120	9.656	.4942	.09936	7.31	71.3	77.8
	180	9.699	.4939	.09931	7.27	76.7	81.5
	240	9.679	.4939	.09878	7.29	87.6	88.7
	300	9.655	.4953	.09858	7.31	88.9	88.9
	360	9.720	.4942	.09817	7.15	89.3	89.3
RIGHT ENGINE	3	1.229	.2505	.05038	115.77	68.6	68.6
	60	1.228	.2489	.05007	114.46	68.6	68.6
	120	1.225	.2485	.04996	114.46	68.6	69.1
	180	1.222	.2476	.04979	114.46	70.0	69.1
	240	1.230	.2485	.04970	113.77	82.6	75.2
	300	1.228	.2496	.04968	114.46	86.5	80.7
	360	1.229	.2491	.04949	113.62	87.6	83.0
LEFT ENGINE	3	1.221	.2489	.05007	115.77	68.6	68.6
	60	1.217	.2463	.04954	114.08	68.6	68.6
	120	1.214	.2457	.04940	113.92	68.6	69.1
	180	1.218	.2463	.04952	113.92	69.1	69.1
	240	1.217	.2454	.04908	113.23	80.9	75.2

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 40 CONTINUED							
LEFT ENGINE	300	1.212	.2457	.04890	113.85	86.5	80.7
	360	1.212	.2451	.04868	113.00	87.6	83.0
RUN 41							
ISOLATION VALVE	5	9.531	.4992	.10209	7.77	48.6	48.6
	60	9.329	.4973	.10107	8.18	83.0	83.0
	120	9.292	.4967	.09993	8.09	86.7	87.4
	180	9.219	.4964	.09946	8.15	88.3	88.7
	240	9.139	.4951	.09926	8.25	85.9	88.7
	300	9.101	.4943	.09912	8.28	83.9	89.6
	360	9.116	.4945	.09925	8.26	82.6	88.7
RIGHT ENGINE	5	1.268	.2511	.05136	111.15	48.6	48.6
	60	1.279	.2505	.05090	109.23	70.2	56.4
	120	1.276	.2505	.05039	108.62	81.3	68.4
	180	1.272	.2505	.05016	108.54	83.7	73.7
	240	1.254	.2483	.04972	109.62	83.0	73.7
	300	1.251	.2481	.04970	109.77	80.0	73.3
	360	1.249	.2483	.04978	110.23	78.3	72.4
LEFT ENGINE	5	1.223	.2481	.05073	116.46	48.6	48.6
	60	1.231	.2469	.05017	114.08	65.7	56.4
	120	1.227	.2463	.04955	113.31	79.3	68.4
	180	1.223	.2460	.04930	113.08	81.5	72.8
	240	1.227	.2469	.04953	113.31	79.6	71.5
	300	1.224	.2463	.04942	113.31	79.3	71.3
	360	1.222	.2463	.04947	113.46	75.9	70.2
RUN 42							
ISOLATION VALVE	1	10.094	.5044	.10335	7.09	47.5	47.5
	60	10.043	.5014	.10278	7.09	48.6	50.7
	120	9.925	.5002	.10258	7.26	53.4	57.3
	180	9.944	.4998	.10254	7.26	58.9	62.7
	240	9.868	.4982	.10142	7.38	85.9	85.9
	300	9.850	.5002	.10111	7.37	86.5	86.5
	380	9.831	.4997	.10056	7.32	87.4	87.4
	405	9.771	.4969	.09983	7.31	87.6	87.6

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	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RUN 40 CONTINUED							
LEFT ENGINE	300	1.212	.2457	.04890	113.85	86.5	80.7
	360	1.212	.2451	.04868	113.00	87.6	83.0
RUN 41							
ISOLATION VALVE	5	9.531	.4992	.10209	7.77	48.6	48.6
	60	9.329	.4973	.10107	8.18	83.0	83.0
	120	9.292	.4967	.09993	8.09	86.7	87.4
	180	9.219	.4964	.09946	8.15	88.3	88.7
	240	9.139	.4951	.09926	8.25	85.9	88.7
	300	9.101	.4943	.09912	8.28	83.9	89.6
	360	9.116	.4945	.09925	8.26	82.6	88.7
RIGHT ENGINE	5	1.268	.2511	.05136	111.15	48.6	48.6
	60	1.279	.2505	.05090	109.23	70.2	56.4
	120	1.276	.2505	.05039	108.62	81.3	68.4
	180	1.272	.2505	.05016	108.54	83.7	73.7
	240	1.254	.2483	.04972	109.62	83.0	73.7
	300	1.251	.2481	.04970	109.77	80.0	73.3
	360	1.249	.2483	.04978	110.23	78.3	72.4
LEFT ENGINE	5	1.223	.2481	.05073	116.46	48.6	48.6
	60	1.231	.2469	.05017	114.08	65.7	56.4
	120	1.227	.2463	.04955	113.31	79.3	68.4
	180	1.223	.2460	.04930	113.08	81.5	72.8
	240	1.227	.2469	.04953	113.31	79.6	71.5
	300	1.224	.2463	.04942	113.31	79.3	71.3
	360	1.222	.2463	.04947	113.46	75.9	70.2
RUN 42							
ISOLATION VALVE	1	10.094	.5044	.10335	7.09	47.5	47.5
	60	10.043	.5014	.10278	7.09	48.6	50.7
	120	9.925	.5002	.10258	7.26	53.4	57.3
	180	9.944	.4998	.10254	7.26	58.9	62.7
	240	9.868	.4982	.10142	7.38	85.9	85.9
	300	9.850	.5002	.10111	7.37	86.5	86.5
	380	9.831	.4997	.10056	7.32	87.4	87.4
	405	9.771	.4969	.09983	7.31	87.6	87.6

R U N 42 C O N T I N U E D

	TIME	AREA SQ.IN	FLOW GPM	FLOW PPS	PRESSURE PSI	INLET DEG F	OUTLET DEG F
RIGHT ENGINE	1	1.233	.2515	.05154	118.08	46.4	46.4
	60	1.229	.2507	.05138	118.08	45.9	45.9
	120	1.231	.2498	.05123	117.08	45.7	45.2
	180	1.223	.2494	.05116	118.08	44.1	44.8
	240	1.225	.2472	.05032	116.77	74.3	54.3
	300	1.236	.2498	.05049	116.08	80.7	63.0
	380	1.236	.2496	.05022	115.08	82.0	68.2
	405	1.225	.2476	.04975	115.00	82.6	70.0
LEFT ENGINE	1	1.239	.2528	.05180	118.08	46.4	46.4
	60	1.229	.2507	.05140	118.08	45.9	45.9
	120	1.233	.2504	.05134	117.08	45.7	45.7
	180	1.228	.2504	.05138	118.08	44.1	44.8
	240	1.239	.2510	.05110	116.77	65.5	54.3
	300	1.238	.2504	.05062	116.08	78.5	63.0
	380	1.237	.2501	.05033	115.08	79.8	68.2
	405	1.232	.2492	.05008	115.00	80.2	70.0

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